BIO-ECONOMIC CONSIDERATIONS FOR WETLAND POLICY ON AN AGRICULTURAL LANDSCAPE

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ABSTRACT

This study looks at land use allocation and wetland management on an agricultural landscape in the Canada's Prairie Pothole Region (PPR) within the context of social, ecological and economic factors. Policy considerations for the conservation of wetlands on an agricultural landscape are examined with a focus on financial incentive-based policy tools. Empirical research looks at the influences on wetland management and the potential for economic incentives in wetland policy. In addition, a spatial approach was employed to develop specific wetland conservation targeting scenarios for two case study farms in two distinct agricultural regions of Saskatchewan. Each targeting scenario was investigated to determine the potential effect on ecological goods and services, particularly carbon sequestration, as well as farm income over time. A hypothetical financial incentive-based wetland conservation program was developed looking at the potential of interplay with private carbon markets.

Land productivity, which is directly related to farm profitability, was the most important factor in predicting farmer participation in wetland conservation voluntarily ($P<0.05$). However, participation in the Environmental Farm Plan program, which provides financial incentives, was influenced by demographic factors such as age and farm size ($P<0.01$) while land productivity had no influence. This indicates that financial incentives may encourage farmers to participate in wetland conservation practices that otherwise would not. The spatial targeting scenarios indicated that trade-offs exist between economic and ecological optimization, the most effective strategies have the highest level of benefits relative to costs and will be readily adopted by farmers. Results also indicate that the publicly funded portion of wetland conservation program payments can be reduced by up to 20% when there is interplay with private carbon markets.

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1.0 INTRODUCTION

1.1. Overview

From society's perspective, in general, wetlands are underprovided on agricultural landscapes in the Prairie Pothole Region (PPR) of Saskatchewan. This thesis investigates land use allocation, wetland conservation and the bio-economic and social considerations for wetland conservation policy in agricultural landscapes in the PPR. There are several considerations for wetland policy in the PPR to achieve a high level of participation, to be cost effective and to provide net environmental benefits. It is difficult for a policy to target all wetland benefits simultaneously; thus, it becomes important to rank benefits and focus on those that provide the greatest welfare improvement for the greatest number of people (Lant 1994). With growing concern about climate change there has been increasing attention paid to the potential of agricultural and wetland soils to help mitigate climate change by restoring and maintaining carbon stores. Thus, wetland conservation strategies were investigated with a focus on carbon sequestration benefits.

This empirical portion of this thesis looks at the potential of economic-incentives in wetlands conservation policy. It looks at wetland conservation targeting strategies to achieve both ecological and economic goals. This study also investigates the role of carbon sequestration and storage in developing wetland conservation policy and the role of carbon-markets to assist publicly funded conservation initiatives.

1.2. Bio-Economic Context

Saskatchewan's agricultural region is primarily made up of the previously glaciated area known as the Prairie Pothole Region (PPR) or the Continental Prairie Wetland Region which encompasses approximately 390 000 km^2 and about 5 % of Canada (Figure 1.1) (NWWG 1988). Wetlands historically made up 23% of the land area in the PPR but it is estimated that 50 -70% of the wetlands in this region have been lost or altered primarily because of agricultural practices (NWWG 1988, EC 1991, Wylynko1999, Huel 2000, Euliss *et al.* 2006). The two major disturbances are: 1) mechanical disturbance of the margin (riparian area); and 2) cultivation or drainage of the entire wetland (NWWG 1988). The continuing decline of wetlands can be explained as a market failure attributed to 1) the public nature of the goods and services provided by wetlands, 2) externalities imposed on stakeholders and 3) inconsistent policies regulating the management of wetlands (Danielson and Leitch 1986, Lant 1994, Heimlich *et al*. 1998, Turner *et al.* 2000).

Figure 1.1 Canada's Prairie Pothole Region (Prairie Ecozone) (adapted from NWWG 1988 Euliss *et al.* 2006).

1.3. Problem

From society's perspective, in general, wetlands are under-provided on agricultural landscapes in the PPR so the purpose of this study is to investigate policy tools, namely economic incentives, to conserve and enhance wetlands ecosystems on the landscape. It also investigates characteristics that influence how wetlands are managed on the landscape and the validity of using economic incentives to encourage farmers to incorporate environmentally beneficial management practices on their farms. Publicly funded conservation programs are quite costly so it is important to consider the role of private markets in meeting conservation objectives.

1.4. Objectives

To address the problem of wetland allocation on agricultural landscapes in the PPR the following objectives are investigated. First, a survey was conducted to investigate the opinions and attitudes of farmers that may influence the way they currently manage wetlands on their farm. Survey data are also used to determine the influences on farmers' willingness to participate in conservation-based programs when financial incentives are present. The second objective uses a spatial approach to develop management scenarios for two case study farms to determine how specific changes in management can affect carbon sequestration as well as farm income over time. The final objective is to investigate the potential for financial incentives in wetland conservation policy. In particular, it looks at the potential for interplay between carbon markets and conservation program payments to achieve conservation objectives.

1.5. Rationale

Employing an interdisciplinary approach is useful in studying complex bio-economic systems to achieve a better understanding of how these systems function. An essential role of economic research is to inform policy makers of strategies that result in an efficient allocation of resources. However, the complexity of bio-economic systems makes it unlikely that an efficient allocation of resources can be accomplished. This is particularly the case with ecological goods and services where the values are often not represented by market prices (Lant *et al.* 2000).

Ecological research is useful in identifying essential levels of ecosystem function for important ecological goods and services to be provided by that ecosystem but does a poor job of capturing the trade-offs between social benefits and private costs. In market-based economic research, economists strive for the most efficient allocation of resources, known as a *Pareto optimal* allocation. In bio-economic research it is unlikely that a truly efficient allocation of resources can occur from both an economic and bio-physical perspective due to the non-market benefits of environmental goods and services. Therefore, policy recommendations are not focused on maximizing economic efficiency or environmental benefits but rather on identifying an improved allocation of resources. This is known as *Pareto improvement* criterion, that is, the winners win (e.g. social environmental benefits) more than the losers lose (e.g. private economic costs) and there is a net gain in social welfare or benefits. This idea can be expanded to include the provision that the winners compensate the losers so that all stakeholders either maintain or improve their current level of welfare or utility (Champ *et al.* 2003).

In terms of wetland policy in the PPR, it is essential to account for the role of wetlands in providing public benefits (e.g. ecological goods and services) and the private costs imposed on farmers for providing these ecosystems. Implementing publicly funded incentives for farmers to manage for healthy wetland ecosystems may lead to improved wetland management and agri-environmental sustainability.

Chapter 2 provides an overview of the considerations given to wetland policy development through a review of the relevant literature. Chapter 3 looks at characteristics of farmers that may influence their participation in environmental management. Chapter 3 also looks at wetland conservation targeting strategies and provides an investigation of the role of financial incentives such as carbon-based payments and conservation program payments as policy tools to encourage the restoration and maintenance of wetlands on privately owned agricultural land. Chapter 4 provides a synthesis and conclusions to the thesis and provides suggestions for future research.

2.0 LITERATURE REVIEW – CONSIDERATIONS FOR WETLAND POLICY

Many new environmental policies that are being developed incorporate the principle of sustainability where the objective is not to achieve an optimal allocation but rather an improved allocation (*Pareto* improvement) (Lant *et al.* 2005). With limited available public funds, the objective of bio-economic studies for policy development is to determine the least-cost approach to conservation goals (Lant 1994 and Yang *et al.* 2005). This chapter looks at policy considerations and options for restoring riparian vegetation and maintaining existing wetlands on agricultural fields in Saskatchewan's PPR.

2.1. Influences on Wetland Allocation in Agricultural Landscapes

The allocation of wetlands in agricultural landscapes in the PPR is influenced by a variety of social, institutional and economic factors. The continuing loss and degradation of wetlands is often explained in economic terms as a market failure attributed to 1) the public nature of the goods and services provided by wetlands, 2) externalities imposed on stakeholders and 3) inconsistent policies regulating the management of wetlands (Danielson and Leitch 1986, Lant 1994, Heimlich *et al*. 1998, Turner *et al.* 2000).

The non-market, public goods and services derived from healthy wetland ecosystems are not considered in the decision making process because the benefits are external to the farm managers. The result is conversion of wetlands to valuable alternative uses (e.g. agriculture production) and wetland allocation on the landscape that deviates from the social optimum for the ecological goods and services provided by wetlands (Danielson and Leitch 1986).

Past and current institutions have played a large role in the destruction of wetland ecosystems by implementing agricultural policies that directly and indirectly promote the drainage and cultivation of wetlands to maximize production (Percy 1993, Heimlich *et al.* 1998, Huel 2000). For example, wetlands are classified as wasteland in Canada's agricultural land inventory system. Wetlands are also viewed as a hindrance to mechanized agriculture and as farm implements continue to expand in size it becomes more difficult to manoeuvre around wetlands on the landscape. As a result of the demand for maximized agricultural production and increases in farm machinery power and size, farmers have been encouraged and enabled to cultivate areas that were previously unsurpassable (Huel, 2000).

Ultimately the market failure associated with wetland allocation on agricultural landscapes suggests government intervention is needed. The role of extension and education are important but have had a minimal impact on how wetlands are actually managed when they are used as the sole policy tool (Weersink 1997, Claassen *et al.* 2001, Benedickson 2002). Alternatively, the use of strict regulation has been avoided due to issues with property rights and the costs associated with compliance and enforcement (Weersink 1997, Claassen *et al.* 2001). The use of financial incentives as a policy tool is a realistic option to help farmers recognize the full value of wetlands and provide the quantity and/or quality of wetland ecological goods and services at the social optimum (Danielson & Leitch 1986, Weersink 1997, Turner *et al.* 2000, Claassen *et al.* 2001, Lant *et al.* 2005). The types of government intervention are outlined in greater detail in section 2.3. First, it is important to understand the current state of wetland policy and legislation that will influence the development of wetland policy in the future, which is the topic of discussion in the next section.

2.2. Current State of Wetland Policy & Legislation

There needs to be a clear understanding of current policies and legislation to understand both the strengths and weaknesses that will guide and limit recommendations for wetland policy in the PPR. Canada was one of the first countries to develop a federal wetland policy framework in 1991 but little progress has been made since that time. One of the mandates of the *The Federal Policy on Wetland Conservation* (*FPWC*) is to achieve zero net-loss of wetlands on federal land and land managed by federal organizations but few provisions have been made to ensure this goal is achieved on privately-owned land. As the *FPWC* has made almost no provisions for private land and the majority of the PPR is private farm land, the influence of this policy on wetland conservation across the landscape is greatly limited.

The demand for action by various levels of government to protect wetlands has been met with limited success. There has been coordination amongst stakeholder groups to advance wetland conservation which has led to a range of policies, legislation and programs across Canada but there is still a long way to go in developing a comprehensive and effective wetland policy (Lynch-Stewart *et al.* 1999). Although traditionally Canadian policies have favoured a regulatory approach, the majority of wetland and environmental policies developed in the last two decades have taken a very different approach. These policies have focused on voluntary stewardship of private lands through conservation programs and extension; forming conservation partnerships; providing exemplary management on crown lands; regional policy frameworks; and continued research (Lynch Stewart *et al.* 1999, Benidickson 2002).

The provinces have jurisdiction over natural resources within their borders including wetlands, while the federal government only has direct authority over cross-boundary resources such as water, wildlife and federally owned lands (Pearse 1988, Percy 1993, Lynch-Stewart *et al.* 1999). The federal government also has concurrent authority with the provinces over agriculture which allows some involvement in wetland issues. However; in the past this power was limited to goals associated with agriculture production and the interprovincial sale and transport of agricultural goods. As wetlands were regarded as a nuisance to agriculture, common law and legislation fostered the removal of wetlands from the landscape (Percy 1993). The federal government also has the responsibility to maintain environmental quality and migratory bird populations under international agreements. In any case, the use of international treaties is usually limited to recommendations and bears no strict legal consequence (Benedickson 2002).

Although there are several statutes that apply to wetland conservation across various jurisdictions, there is not a comprehensive statute in any Canadian jurisdiction dedicated exclusively to wetlands (Lynch-Stewart *et al.* 1999). There are issues of duplication between levels of government and within the various government departments which has exacerbated the problem of regulating wetland management (Shutzman 2007).

2.2.1. Federal Policy and Statutes

Canada’s agreements under international treaties initiated the development of wetland policy and regulation in Canada. In 1981 the government of Canada signed on to the *Ramsar Convention on Wetlands*. This is an international treaty to conserve wetlands of international importance by encouraging the “wise use” of wetlands. The *North American Waterfowl Management Plan* (1986) and the *Convention on Biological Diversity* (1992) are also international agreements that encourage wetland conservation for maintenance of wildlife habitat and biodiversity (Lynch-Stewart *et al.* 1999). These international agreements led to the development and implementation of *The Federal Policy on Wetland Conservation* in 1991.

The Federal Policy on Wetland Conservation (*FPWC*) is a federal policy that directs all departmental agencies to promote wetland conservation in their policies and programs. It is meant to complement other international and federal policies regarding wildlife, fisheries and oceans, forestry and agriculture. The objective of *FPWC* is to “*promote the conservation of Canada's wetlands to sustain their ecological and socio-economic functions, now and in the future*”. Perhaps the most important objective of the *FPWC* is no-net loss of wetlands. Canada has also developed Canada’s Wetland Mitigation Project, a response to *FPWC*. This project has a hierarchical planning process; the primary goal is disturbance avoidance and outright protection of wetlands. Where full protection is not feasible, the second goal is to minimize ecosystem impacts where development activities have occurred or are occurring. The final goal is the restoration or rehabilitation of previously degraded sites (Lynch-Stewart *et al.* 1999, Cox and Grose 2000).

Lynch-Stewart *et al.* (1999) identified two common misconceptions about the *FPWC* that hinder its full and proper implementation. The first misconception is that many people recognize the *FPWC* as being an Environment Canada policy. However, all federal departments are responsible for its implementation and financing. The second is that it is viewed to apply only to federally managed lands. In fact, it is meant to apply to all federal programs, policies and expenditures, following the guidelines of the *Canadian Environmental Assessment Act* (1992). However, as was mentioned earlier, the *FPWC* has limited influence on privately owned lands and is unlikely to have a significant impact on wetland conservation across the landscape.

There are a handful of federal statutes that contribute to the wetland conservation effort. The *Canadian Environmental Assessment Act* (1992) (*CEAA*) is probably the most powerful federal statute in terms of wetland conservation across Canada. It sets out the procedures involved in environmental assessments related to projects involving the federal government. This includes projects where the government is selling, leasing or transferring control of land; providing funding or assistance to a project; or where it exercises permitting authority (Lynch-Stewart *et al*. 1999). This statute requires that environmental effects are considered in the early stages and throughout the duration of all development projects. Unfortunately, this statute does little to protect isolated wetlands on private agricultural fields in the PPR. One instance where this act may apply is if farmers applied for federal funding to drain wetlands on agricultural land. For example, loans obtained from Farm Credit Canada for farm development projects would fall under the umbrella of the *CEAA*. It is important to note that the courts have narrowly construed the meaning of a “development” for purpose of the *CEAA*, thus many activities are not considered development and as a result not subject to an environmental assessment. Therefore, the ability of the *CEAA* to contribute to wetland conservation is minimal.

The *Canadian Environmental Protection Act, 1999* can be used to protect water resources but its focus is on pollution issues rather than habitat preservation. The main goal of *CEPA 1999* is to protect the environment and human health by managing and preventing risks associated with toxic or harmful substances. Therefore, the *Act* can prevent degradation of wetlands from pollution but has no authority to regulate the outright protection of wetlands. Furthermore, as most pothole wetlands are isolated and do not contribute to a larger watershed, pollution of a single wetland will not pose a serious threat to public health or the environment and is therefore not a concern under the *Act*.

It is also unlikely that inspection, let alone enforcement, would occur on wetlands found entirely within a single owner's private property for a few reasons. First, there is a strong will not to interfere with resources found entirely within a single owner's private property, which is the case for many wetlands (SWA 2006). Second, the large number of wetlands in the PPR (approximately 4 million according to NWWG (1988)) makes monitoring and enforcement of the *Act* highly difficult for every wetland. Finally, most wetlands in Saskatchewan's PPR are relatively small in size, with 37-63% of wetlands less than 0.2 ha in size and few exceeding 10 ha (NWWG 1988), the overall environmental and health impacts of the degradation of a single wetland are minimal. Unfortunately, environmental legislation across Canada considers only single projects or ecosystems (e.g. a single wetland) at a time therefore the cumulative impacts of wetland degradation are not addressed by *CEPA, 1999* or other environmental legislation for that matter (Shutzman 2007).

Federal statutes that protect wildlife and wildlife habitat have the potential to protect wetland ecosystems but in reality these statutes do little to protect wetlands in the PPR. The *Migratory Birds Convention Act* is meant to protect wildlife habitat but its only strict regulation in regards to wetlands is the prohibition of depositing harmful substances into wetlands important to migratory birds (Percy 1993 and Lynch-Stewart *et al.* 1999). The application and enforcement of this *Act* on isolated wetlands on private farm land is highly infeasible for the same reasons outlined for *CEPA 1999*.

The *Canada Wildlife Act* enables the department of the environment to undertake conservation programs and research in partnership with other governments and organizations. It also enables the establishment of "National Wildlife Areas" and "Marine Wildlife Areas" to protect areas of ecological significance. The *Act* prohibits human activities that are harmful to wildlife and to the environment which can result in fines up to $250,000 and/or the cost of remediation. There are more than 287, 000 ha of wildlife habitat protected by the *Act* with wetland covering about 40% of the area but this *Act* does not affect private lands (Lynch-Stewart *et al*. 1999). Therefore, the wetlands of concern in this study are not subject to protection under the *Act*.

The *Fisheries Act* specifies the authority of the government to regulate both inland and oceanic fisheries. There are a wide range of penalties for damaging fish habitat. This is a potentially powerful tool for wetland protection providing the wetlands provide habitat for fish that are important to a fisheries industry; however, few wetlands in the PPR would fall under this category (Percy 1993).

Under the *Species at Risk Act* (2003) it is prohibited to "*kill, harm, harass, capture, or take an individual of a species listed in Schedule 1 of SARA as endangered, threatened or extirpated"* and it is an offense to damage the habitat or residence of listed species. On privately owned farm land the *Act* only applies to aquatic species and migratory birds. Although this is a potentially powerful tool for wetland protection where species at risk occur, it is largely the responsibility of the land owner to report species at risk as it is unlikely that federal officials would be able to detect these species without cooperation of the landowner.

Perhaps the policy with the most potential for wetland conservation in the PPR at the federal level does not come from statutes but from the new Agriculture Policy Framework (*APF*) (AAFC 2008). Although there are no regulations under the *APF*, the incentive structure may be used to encourage farmers to manage for healthy wetland ecosystems on their agricultural land. The *APF* is made up of five complementary elements: business risk management; food safety and quality; science and innovation; environment; and renewal. Farmers that conduct an environmental farm plan (EFP) are eligible for government funding when they implement beneficial management practices on their farms. Under the environmental element, wetlands are recognized as being an important ecosystem component and wetland restoration and riparian management are listed as beneficial management practices.

Even though the *APF* recognizes the importance of managing for ecosystem health on agricultural lands, the overall goal is still to maximize production. For example, major farm income subsidy programs such as the Canadian Agricultural Income Stabilization Program (CAIS) are still based on crop acreage and yield as opposed to the provision of environmental goods and services. Furthermore, the policy provisions that address environmental management are focused on ecosystem restoration rather than protection (Lovell and Sullivan 2006). It can take 8-50 years for restored wetlands to provide the same functions as a natural wetland, so although restoration is important, it is obvious that more attention needs to be put on the preservation of wetlands that still exist as they can provide more benefits to society in both the short and long terms (Gutrich and Hitzhusen 2004, Lovell and Sullivan 2006).

2.2.2. Saskatchewan's Provincial Policy and Statutes

In general, the current policies and statutes of Saskatchewan recognize the importance of healthy ecosystems including wetlands but they do very little in terms of regulation and protection. In addition, the residual effects of early policy and legislation that encouraged the destruction of wetlands for agriculture production, in particular the *Northwest Irrigation Act 1894* and the *Dominion Lands Act* (1872), are still apparent in how wetlands are actually managed today (Percy 1993). The wording of existing statutes that could possibly be used to protect wetlands is often vague and open to interpretation; it is unlikely that wetland protection claims under these current provincial statutes would stand up in court (Bowden 2007). The statutes tend to focus more on partnerships, and research and education. While these are important elements, they are insufficient in protecting wetlands.

Following the federal government's example, the *Saskatchewan Wetland Policy* was adopted in 1995 to recognize the importance of wetland conservation in Saskatchewan. This policy was followed by the *Water Management Framework* in 1999 which listed water management strategies that have now been incorporated into the *Saskatchewan Watershed Authority Act, 2005*. The protection of wetlands through the *Saskatchewan Wetland Policy* is focused on agricultural regions as the wetlands in these regions are most threatened. The objectives of the *Policy* are:

- *"To encourage sustainable management of wetlands on public and private lands to maintain their functions and benefits.*
- *To conserve wetlands that are essential to maintain critical wetland species or wetland functions.*
- *To restore or rehabilitate degraded wetland ecosystems where previous destruction or alteration has resulted in a significant loss of wetland functions or benefits."*

Two important aspects of the *Saskatchewan Wetland Policy* are the acknowledgement of private landowner and aboriginal rights and it encourages an integrated approach to wetland conservation by focusing on partnerships with governments, industry, conservation organizations and individuals (Lynch-Stewart *et al.* 1999 and Annand *et al*. 2002). However, the *Policy* lacks, arguably, the most important mandate for wetland protection which is no net-loss, and ignores the most threatened wetland ecosystems which are seasonal wetlands on agricultural lands. The definition of wetlands under the *Saskatchewan Wetland Policy* is as follows:

> *"both the wet basin and an area of transitional lands between the waterbodies and adjacent upland…The transitional lands are a minimum of 10 metres (33 feet) adjacent to the area covered by water at the waterbody's normal full supply level... low-lying areas predominantly under cultivation are not considered wetlands, as they have been converted to other uses."*

The *Saskatchewan Watershed Authority Act, 2005* (SWA) is the central piece of regulatory legislation for wetlands in Saskatchewan that aims to manage and protect Saskatchewan's water resources. Wetlands are included in the *Act*'s definition of surface water which includes "*water that is above the surface of land and in a river, stream, lake, creek, spring, ravine, coulee, canyon, lagoon, swamp, marsh or other watercourse or water body*." But, as noted in the above definition of wetlands, this act does not recognize seasonal wetlands on agricultural fields.

Although the *SWA Act, 2005* is relatively new, it has been largely deemed as inefficient in protecting wetland resources because the principles of the act still strongly resemble legislation stemming from the settlement of the prairies more than a century ago, in particular the *Northwest Irrigation Act, 1894* (Bowden 2007). The broad conservation mandates simply state ways in which wetlands may be effectively managed. The ambiguous wording and broad statements used throughout the *SWA Act, 2005* makes it difficult for administrators to gain direction and undermines any attempts to regulate under the *Act* (Bowden 2007). For example, section 38 suggests that the crown has the right to manage and regulate all wetland resources but further investigation of the *Act* reveals that SWA can delegate water rights at its broad discretion. As another example, wetland drainage works require approval from SWA but the approval of a drainage project does not apply to drainage projects on private land where the drained water does not leave the owners land. This essentially deems the regulation useless as many drainage projects only affect the owners land. For example, many wetland drainage projects will divert water into one large wetland or into a creek or river that intersects the owners land. It is rarely an issue for drainage projects to affect other land owners. However, when drainage projects do affect other land owners the legal issue is not wetland protection but flooding of another farmer's land, thus reducing the agricultural capability of the neighbouring land.

The *Conservation Easements Act* is identified in the *Saskatchewan Wetlands Policy* as an important tool for conservation. Conservation easements allow landowners to place a voluntary easement on their property to protect ecological goods and services that is protected by law and transfers with title. Conservation easements are highly varied in the ecosystems they protect and the management practices that can still occur on the land. They range from strict land retirement to allowing some development or agricultural practices that do not compromise the integrity of the ecosystem of concern. However, because conservation easements exist on relatively small tracts of land they do not contribute significantly to the overall conservation effort. Also since they are voluntary, there is no guarantee that those areas in the greatest need of protection will ever benefit from conservation easements.

Other provincial legislation that applies to wetland management includes Saskatchewan's *Environmental Assessment Act* which has similar objectives and enforcement measures as the federal act. This *Act* enforces that in the planning phases of development projects the environmental implications be considered. Similar to the federal act, the Saskatchewan *Environmental Assessment Act* also has limited application due to the narrow scope of activities considered to be development projects. In addition, there is not a specific requirement for considerations to be given to wetland conservation and it is unlikely that this act would be applied to privately managed, agricultural lands. Likewise, *The Environmental Management and Protection Act, 2002* which regulates and prevents "adverse effects" to the environment, is unlikely to be applied to wetlands in agricultural fields. This act is meant to complement the *Saskatchewan Watershed Authority Act, 2005* in that it includes penalties for water quality related issues. However, it does not have any specific provisions for wetland conservation.

Provisions for wetland conservation have been made in wildlife and resource statutes such as *The Natural Resources Act, 1993, The Wildlife Act, 1998* and *The Wildlife Habitat Protection Act* but the powers of these statutes are more enabling than mandatory and focus more on extension and education. *The Wildlife Act, 1998* has tools for protecting species at risk that require ecosystem maintenance and management for habitats of species at risk. It is unlikely that these powers would be enforced on private farm lands for the protection of isolated wetlands. Most of the powers in these statutes are reserved for implementation on crown lands.

As this discussion indicates, while wetland conservation policy exists at both the provincial and federal level the policy tools currently used to meet environmental objectives (e.g. extension, research, conservation easements and regulations) are inefficient in protecting wetland resources on their own, particularly on privately owned land. The lag in efficient policy development can be costly to the environment. The longer that policy lags, the more powerful economic enterprises become entrenched in our society and it becomes more difficult to regulate them (Pearse, 1988). There is ever increasing tensions between resource developers and environmental organizations. As society becomes used to certain practices regardless of whether or not they have a legal right to them, it is difficult to change or prevent these practices from occurring (Pearse, 1988).

One of the barriers to effective wetland conservation policy on agricultural landscapes has been limited knowledge on how to manage for healthy wetlands and riparian areas in these landscapes (Lovell and Sullivan 2006). This limited knowledge is often attributed to incomplete wetland surveys, difficulties identifying the areas of greatest concern, and the continued need for research into the best policy approach. Furthermore, research is often funded by agribusinesses that are interested in maximizing profits; this has resulted in scientists favouring private economic interests over social interests (Blesh & Barrett 2006). However, other countries faced with similar problems, such as the United States and Australia, have implemented strict regulatory policies on wetland protection. Perhaps the best explanation for a poorly developed wetland policy in Canada is the lack of political will (Farnese 2005).

Difficulties in developing efficient environmental policies are also attributed to issues with property rights, particularly in terms of regulation on private lands. Due to the significance of property rights in environmental policy the following sub-section has been dedicated to this issue.

2.2.3. Property Rights

The term property right refers to the bundle of rights that defines the privileges and limitations to the use of particular resource. In this definition property is not an object, but rather a collection of entitlements (Ziff 2000, Tietenberg 2006). In essence a property right can be thought of as a relationship between an object of interest (either tangible or intangible), the individual or group of individuals related to the object of interest and all others who are enforced to respect the right (Kaplowitz 2000, Ziff 2000). The well defined property right of ownership, often referred to as private property, includes the right to possession; management and control; income and capital; trade and transfer; and protection under law.

Property rights are a common issue when developing environmental policy whether it is in a legal or economic context; however, the application of the property rights differs greatly between the disciplines. In economics, researchers often create or assign property right distributions that help explain allocation of resources. This assignment of property rights is a useful tool for economists when rights are not well understood. However, legal property rights are interpreted in accordance with the law. Understanding how the property rights for a particular resource are allocated to potential stakeholders is interpreted through a combination of provincial and federal legislation as well as common law. The current understanding of property rights under the law guides and limits the type of policy that can be developed (Percy 1993).

Property rights for environmental goods define the rate of use and ultimately stewardship objectives. The composition of property rights and the distribution of rights among stakeholders will affect the incentive scheme needed to achieve conservation objectives (Allan 2005). Unfortunately, in the case of the environment it is rare to have well defined, individual property rights. Poorly defined individual property rights leads to the presence of externalities, public goods and common property resources (Kaplowitz 2000). Thus, the problems associated with environmental degradation are often explained as a market failure in the context of property rights.

Problems with undefined individual rights to property often arise when there is a sudden change in value of a resource often due to real or perceived scarcity. This can occur when there is a change in social beliefs regarding the value of a particular resource, for example the public recognition of benefits associated with healthy wetland ecosystems. Prior to the change in value, there is little need to understand the property rights associated with a resource; however when the change in value is recognized, it becomes essential to determine who is entitled to benefit or alternatively who carries the burden of the resource. The development of policies generally follow changes in social beliefs but this lag to policy development can be costly to the environment (Pearse 1988). According to Pearse (1988), the longer that policy lags, the more powerful economic enterprises become entrenched in our society making it more difficult to regulate these enterprises. In the past, land use policy in the PPR has tended to favour drainage and cultivation of wetlands because the social values of wetlands were not recognized. Thus, even though society now recognizes the value of wetlands, it is extremely difficult to develop policies that protect society's perceived environmental rights as these rights conflict with deep rooted traditions (Pearse 1988).

One of the major issues with developing environmental policies is identified by Kaplowitz (2000) as presumptive property rights; opposing groups presume they have a right which leads to conflict over the management of the resource. In some cases the property rights have already been assigned, there is simply a misunderstanding or ambiguity as to how they can be regulated. For example, wildlife is crown property, however the right to regulate wildlife found on privately owned land is not well defined or understood. In most cases the property rights have not been clearly defined and conflicts are a matter for the courts. In the case of wetlands in a private property scenario there are generally two views: 1) private landowners claim that they hold the right to do as they wish with the resources on their land and 2) the public has a right to environmental amenities derived from resources on private land and management decisions should be made in the context of socially acceptable behaviours. The conflict between opposing views is exacerbated by ambiguity in current statutes. For example, neither environmental nor property rights are clearly protected by Canada's *Charter of Rights and Freedoms*, but this does not mean that these rights do not exist implicitly in other constitutional provisions (Benedickson 2002). For example, section 7 of the *Charter* states that "*everyone has the right to life, liberty and security of person and the right not to be deprived thereof except in the principles of fundamental justice*". This can be interpreted that society implicitly has environmental rights as they are to be free of threats to life and health which can include environmental degradation. Alternatively, it can be interpreted that those who derive livelihood off of the land should be protected, suggesting individual property rights exist. This ambiguity regarding rights makes regulation of wetland management in a statutory framework very difficult. The provincial governments have the authority to impose strict regulations on wetlands found on private property, however this is not an optimal or a desirable solution within the current interpretation of individual private property rights by both the landowners themselves and society. This has largely been influenced by past institutions that favoured individual property rights even though there was no strict legal protection of these rights. Since environmental rights are a relatively recent concern they tend to have less support from individuals and society than individual property rights.

> "Public support for wetland protection is strong, but especially among landowners, there is also a very strong interest in protecting the landowner's right to manage his or her own land and therefore, resistance to a regulated approach to wetland protection" (SWA 2006).

An often over-looked characteristic of individual property rights are the responsibilities that come along with them such as prohibition from harm. These ownership responsibilities may be enforced through social expectations or by law which has been the European Union's approach to environmental management and conservation (Ziff 2000). However, the nature of the EU's landscape (i.e. the fact that it is densely populated) makes compliance and enforcement possible, such a policy would be difficult to implement in Canada where vast tracts of virtually uninhabited land makes compliance and enforcement highly infeasible.

Property rights are always a concern when making recommendations to policy makers. In the case of environmental goods and services, Mitsch and Gosselink (2000) and Olewiler (2004) argue that representing governments have the right to protect public goods and it is their responsibility to work with private landowners to achieve environmental objectives. However, the right to regulate for environmental benefits on privately owned land is not implicit in current statutes. Fortunately, regulation is not the only means to meet environmental objectives and understanding that individuals respond to incentives provides governments with an array of tools to meet environmental objectives while respecting the current interpretation of private and public property rights.

2.3. Approaches to Sustainable Wetland Policy Development

It is important that policies are economically and environmentally sustainable. Thus, the World Commission on Environment & Development (1987) recommended that environmental and economic considerations be integrated in decision making. Good policies are those that target funding to the areas where benefits are greatest relative to costs, allow producers the flexibility to meet environmental objectives and involve program co-ordination to avoid duplication and to offset costs of each other (Claassen *et al.* 2001).

An agri-landscape wetland policy refers to the group of programs and policy tools that can be used to encourage farmers to participate in management of wetlands for environmental benefits. In the past, agri-environmental policies focused on pollution prevention; this focus gradually shifted to the protection of specific environmental benefits that also provided private benefits to landowners (e.g. soil conservation). The latest shift in environmental policy is to broaden the definition of environmental protection to ecosystem and landscape protection to ensure the provision of all ecological goods and services as opposed to targeting a single benefit (Claassen *et al.* 2001, Benedickson 2002). While conceptually the ecosystem approach has taken hold in society and with policy makers there is yet to be legislation passed that truly reflects the ecosystem approach.

A variety of policy tools can be used to meet wetland conservation objectives ranging from voluntary to mandatory. There are four categories of policy instruments commonly used to meet environmental objectives: 1) research & extension 2) spending and investment 3) economic incentives and 4) regulation. Regardless of the policy tools utilized, several considerations must be taken into account when developing wetland and environmental policy as outlined by Benidickson (2005) and DeMarco (2007).

1. Environmental & Property Rights – The public's environmental rights need to be formalized in legislation so that they are given the proper weighting in economic decisions. Meanwhile the property rights of farmers also need to be respected and weighted accordingly in the decision-making process. This is complicated by the fact that public environmental rights and private property rights are often in conflict.
2. Polluter Pays Principle – This emphasizes that polluters should be responsible for the harmful environmental costs associated with their activities.
3. Precautionary Principle – This states that even in the absence of scientific evidence of harm early preventative action is appropriate where the environmental risks of human activities are uncertain but potentially great. It also acknowledges the importance of leaving wide margins of ecosystem tolerance to disturbance so that natural systems will be able to adapt to human induced changes. Those who wish to engage in an activity with uncertain environmental impacts are responsible for proving that the potential impacts would be within a tolerable range.
4. Intergenerational Principle & Sustainability – Consideration will be given to both the current and future generation's welfare. Enjoying gains in welfare now should not be at the expense of future generations and vice versa. The principle of sustainability recognizes the interconnectedness of the economy and the environment; environmental goals must be met in ways that encourage economic prosperity. Legislation and policy must be developed

that is flexible for this continually evolving relationship between the environment and the economy.

5. Public Trust – This confirms the obligation of the government to "safeguard" the environmental integrity of state property for the benefit of current and future generations.
6. Inherent Value – This acknowledges the value of an ecosystem in itself, this is also known as a non-use or existence value. Despite the non-market nature of these values, they should be given appropriate weighting in environmental decision making.
7. Ecosystem Approach and Ecological Integrity – Ecosystems are complex, interconnected systems that do not act in isolation of their surroundings. Changes to even the small components can have large ecosystem effects. For example, elimination of a single species can lead to the collapse of the entire ecosystem. Protecting ecological integrity acknowledges the importance of all components of the system to healthy functioning of the ecosystem. When an ecosystem is healthy and performing all of its natural functions, the social benefits from that ecosystem can be maximized. Although it is extremely difficult to understand the complexity of these ecosystems, management practices need to take this into consideration.
8. Pollution Prevention – This coincides with the polluter pays and precautionary principles in that it is more cost-effective to prevent pollution than to have to take remedial action in a future time period.
9. Cumulative Effects – This corresponds to the ecosystem approach. A single small disturbance is not likely to harm a system but several small disturbances can have a huge and damaging cumulative effect.

10. Access to Information (right to know) – The public has a right to know the state of the environment and should be made aware of any development projects that may adversely impact the environment. This principle has been commonly adopted in environmental legislation.

To reiterate and expand upon existing wetland policies, in the PPR where wetland numbers are at a critical level to provide important ecological goods and services and are particularly vulnerable to climate change (Johnson *et al.* 2005), policies must address the need for continued wetland protection to achieve no net loss of wetlands (Farnese 2005). Wetland policy in the PPR will require an array of tools to meet objectives; perhaps the most important consideration in choosing policy tools is how the costs will be distributed between farmers, consumers and the government/taxpayers.

2.3.1. Regulation

Regulatory policy tools are a direct mechanism that require environmental standards to be met regardless of the private expenses incurred. Environmental regulation can be achieved through a combination of statutory law, tort law and contractual law. Statutes that can be used to protect the environment are found in direct environmental laws, corporate law and tax law (Benedickson 2002). The provisions in these statutes for environmental protection are generally focused on environmental pollution, usually incorporating the "polluter pays" principle (Weersink *et al.* 1998). Although there has been a shift in environmental policies toward ecosystem maintenance, regulatory tools still tend to be based on pollution prevention and remediation as can be seen in the *Canadian Environmental Protection Act, 1999*. In general, regulation is warranted when environmental risk is high and society's acceptable level of tolerance for environmental degradation is low. Thus, regulation is often used in the case of public health and safety concerns, in highly environmentally sensitive areas and where changes are irreversible as in the case of species extinction (Weersink 1997 and Claassen *et al.* 2001).

In the past regulatory policy tools were largely avoided for environmental protection due to enforcement difficulties and issues with property rights encountered with regulatory policies (Claassen *et al.* 2001). Regulation represents an extreme approach to environmental management where participation is involuntary and there is no direct financial compensation for compliance but non-compliance may result in fines. As a result, regulation can be the most effective tool in improving environmental quality in a short period of time. However, this type of program does not allow farmers the flexibility or freedom to opt out if management changes are too costly. As well, past agriculture policies supported and subsidized farm income and there is a perceived need for this to continue which is in conflict to environmental regulation (Weersink *et al.* 1998). Admittedly, a strictly regulatory approach to wetland protection would be inequitable especially in the prairie agricultural region where the vast majority of wetlands occur on private farm lands. Since society reaps the benefits of environmentally beneficial management practices, it is often perceived by both private landowners and policy makers as unfair to expect farmers to bear the full burden of providing these ecological goods and services to society. Therefore, in terms of wetland conservation policy, there is a need for policy that mandates wetland protection and provides compensation to those who produce the goods. The cost of regulation on individual farmers may be alleviated through low interest loans or financial assistance programs (Weersink et al. 1998). However, it is also important to consider the level of environmental protection farmers should be responsible for providing to society as it is recognized that ownership of land confers both rights and responsibilities to the landowner (Frey and Oberholzer-Gee 1997, Reeson and Tisdell 2006). The issue of landowner responsibilities to society is discussed in further detail under economic incentives in section 2.3.4.

Regulation is not only costly for individuals forced to comply but also for taxpayers as the cost of establishing government standards, and then monitoring and enforcing them, are very high. Enforcement is particularly difficult for performance-based policy where the damages/benefits of an individual farmer are difficult to directly observe and monitor. Alternatively, management-based policy, particularly land-retirement objectives (e.g. wetland and riparian areas), is much easier because individual farmers and their practices can be monitored by using of satellite images and GIS applications (Weersink *et al.* 1998). However, there is a need to consider political realities such as a policy maker's main goal of re-election. As such, they may be averse to implementing policies with strict regulations on private farm land unless there are land-use effects that negatively impact life-supporting ecosystems (Weersink *et al.* 1998 and Claassen *et al.* 2001).

It is unlikely that regulation alone will be able to play a large role in wetland conservation in the PPR. When considering only an individual farm or a single wetland, the removal of isolated wetlands is not considered to contribute significantly to overall landscape function. However, the cumulative effects of wetland loss across the landscape can have very significant and negative impacts on the environment. Thus, it is important to consider options to ensure a minimum provided standard for wetlands on the landscape. A minimum standard for wetland conservation may be achieved through cross-compliance programs which use a combination of regulation and economic incentives. Compliance instruments require a standard level of compliance to be eligible to participate in other income support programs. A good example of a cross-compliance program is the United States Swampbuster Program. To achieve a mandate of no-net loss of wetlands, support benefits from all government funded farm programs are denied to farmers who plant crops in wetland areas or who drained or altered wetlands after 1985 (EPA 2008). Thus, the onus is placed on farmers to prove that no wetlands have been drained or altered for the farmer's land to be eligible for other income support programs.

Considerable technical assistance is required for cross-compliance programs and compliance verification and enforcement may be costly (Classen *et al.* 2001). However, if the most costly environmental management practices are used as the criteria to be met before other programs can be triggered, cross-compliance programs are likely to cost less overall than other economic-incentive programs (Weersink *et al.* 1998). To achieve significant participation in cross-compliance programs, incentive payments have to be significant and attractive to farmers (Claassen *et al.* 2001).

Another regulatory mechanism is licensing controls. Licensing controls can be used to regulate management practices such as wetland drainage or cultivation. However, these types of licenses are avoided on private lands unless negative effects from an activity are tangible and external to the land owner. For example, in the *SWA Act, 2005* drainage requires a license but it is rarely enforced and does not apply to privately-owned lands where water does not leave the owner's land.

Government labelling standards can also be used to regulate for environmental management. Labelling standards recognize farmers for participating in beneficial environmental management practices by labelling consumer products so that the farmer earns a premium price (e.g. organic products). Like compliance mechanisms, labelling standards combine regulation with economic incentives. Although this is a voluntary program, enforcement measures, in the form of third party verification, are still needed for those who enrol in the certification program. One of the advantages of certification program is that consumers are made aware of the beneficial management practices that go into production of labelled products and can make a conscious decision to support these types of practices. In addition, having a national labelling standard can help facilitate domestic and international trade that provides direct economic benefits to the producer (Weersink *et al.* 1998 and Claassen *et al.* 2001). Environmental standardized labelling as policy tool is only useful if gains from participation can be captured in the market (Claassen *et al.* 2001). Although it is possible that wetland conservation policy can benefit from labelling of commodities produced on farms that provide wetlands, there has been no directly applicable research to support this approach to wetland conservation policy.

Regulation can also be used as a means to establish markets (Weersink *et al.* 1998). For example, the introduction of greenhouse gas emissions caps led to the creation of carbon markets. The use of carbon markets to meet environmental objectives is central part of the discussion in the economic incentives section 2.3.4 as well as in Chapter 3.

2.3.2. Land Retirement & Investment

Governments can take an active role in environmental protection by purchasing land for retirement. This is a very costly practice and is not feasible for large tracts of land. Furthermore, there may be resentment towards the government for competing against farmers to purchase land that is perceived to be suitable for agricultural production (Claassen *et al.* 2001). The only time that purchase of land is warranted is for highly ecologically sensitive areas. An alternative to purchasing land is to purchase conservation easements (Byrne 2005). These are voluntary agreements that landowners enter into to conserve environmental resources in perpetuity. In general, conservation easements apply to an entire parcel of land and dictate the type (if any) of management practices that can occur on that parcel of land. Management restrictions on conservation easements range from complete retirement of the land to allowing certain development projects as long as the ecological integrity of the property is not compromised. A more detailed discussion of conservation easements was provided in section 2.2.2. The difficulty with the voluntary nature of conservation easements is that there is no guarantee that the land that needs to be protected the most will be enrolled in the program (Claassen *et al.* 2001).

2.3.3. Extension, Research and Technological Innovation

Extension is a policy tool to disseminate information to farmers through education and technical assistance which can be delivered by the government, independent consulting firms or conservation organizations. Extension tools can be used to encourage wide adoption of practices by increasing awareness about conservation practices with farmers. However, participation in extension programs is generally not mandatory and those who do participate do not necessarily adopt the recommended beneficial management practices (Weersink *et al.* 1998). For these reasons, to be an effective tool extension services often target practices that also benefit the producer by lowering production costs, increasing productivity or reducing damages to resources that farmers use such as groundwater (Claassen *et al.* 2001). Where private costs exceed benefits, the responsibility of environmental management falls on those who feel a moral responsibility, yet the farms that participate in environmental management are not necessarily the farms with the potential to produce greatest benefits (Weersink *et al.* 1998).

An extension program can also be successful if it is partnered with economic incentives or regulations. Education and technical assistance programs were the primary environmental conservation policy used throughout the majority of the 20^{th} century but they were relatively ineffective in encouraging environmental management when implemented as the sole policy tool (Weersink *et al.* 1998 Claassen *et al.* 2001, Benedickson 2002). Extension efforts have increased awareness of environmental practices but these do not guarantee that farmers will consciously manage for healthy wetland ecosystems. The high cost of extension programs relative to the level of environmental benefits they provide indicates that extension may be an insufficient tool on its own but may serve to support or complement economic incentive or regulatory programs. For any program or policy to be successful, potential participants must be made aware of both the benefits and costs of the policy so that they can make a rational decision to participate and/or choose the most effective strategy to comply. Extension and technical assistance is critical to disseminate this information.

Government funding can also be used to support and encourage research of environmentally beneficial management practices or technological innovations that reduce human impact on the environment yet maintain income stability. An example of such an innovation was the development of zero-till crop production. The need for soil conservation while maintaining farm income was largely responsible for this technological advancement. Often regulation or incentives are needed to encourage such technological innovation (Weersink *et al.* 1998).

Investment in technology has also resulted in large advances in satellite and GIS technologies. These technological advances have allowed policy-makers to cost-effectively target conservation programs by integrating physical, social and economic data into a user friendly framework across disciplines to conduct benefit-cost analysis. The use of satellite imagery and data collection has greatly reduced the need for intensive field data collection to make informed policy decisions. For example, GIS applications have been used extensively over the last decade for wetland conservation research by spatially delineating the most cost-effective areas to meet environmental objectives. Although the majority of these studies have focused on sediment abatement and pollution control (Yang *et al.* 2003, Yang and Weersink 2004), it is possible by using GIS technology to measure other ecological goods and services as well as costs associated with the implementation of specific beneficial management practices across a landscape to establish a cost-effective policy strategy.

2.3.4. Economic Incentives

Economic incentive instruments can be used to internalize the positive societal benefits that are otherwise external to farmers making management decisions, thus correcting inefficiencies in land use allocation (Weersink *et al.* 1998). To correct the inefficient land use allocation from society's perspective, economic incentives can either be positive and voluntary by providing farmers with payments to encourage environmentally beneficial management practices, or negative and involuntary by taxing farmers for environmentally harmful activities. In general it is felt that farmers should be compensated for providing public goods, this is sometimes referred to as the provider-gets approach, so the majority of financial incentive programs provide positive incentives (Claassen *et al.* 2001 and Weersink *et al.* 1998). Incentive programs are viewed as being more flexible than regulatory regimes because they allow farmers to weigh the costs and the benefits before they choose to participate in the program. In addition, farmers are considered to be well informed decision-makers; therefore, they will choose the strategy that yields the most private benefits at the least cost, or if the costs are too great they will not adopt the program. This inherently selects the most cost-effective farms to adopt the program (Weersink *et al.* 1998). However, the efficiency of the program is greatly influenced by the program design and the payment mechanism and amount.

One economic incentive design is a cost-share incentive program. Farmers pay for the adoption of beneficial management practices and the cost share program may cover a portion or all of the costs. This is the approach taken by Canada's National Farm Stewardship Plan (NFSP). When beneficial management practices (BMP) have been identified in farmers' environmental farm plans, they can apply to the NFSP to cover up to half of their costs of implementing the BMPs (PCAB 2006). If cost-share payments do not exceed the costs and there are no or limited private benefits, it is unlikely that farmers will participate. However, if the payments exceed the cost then the program represents an income support which is costly to taxpayers (Claassen *et al.* 2001). Cost-share programs are most-effective in implementing management changes that maintain or improve private profitability such as management changes that still allow crop production. For example, a cost share program that helps farmers implement zero-till should be widely adopted because crop production can still occur and soil productivity is often improved while environmental benefits such as a reduction in soil erosion and improved wildlife habitat are also achieved. Thus, supporting environmental management practices that support continued crop production on the land may be more cost-effective than land retirement options but the benefits are also not as great (Feng *et al.* 2006). Again, using the zero-till example, the land can remain in production, thus, maintaining and possibly improving farm income. However the benefits of erosion reduction, carbon sequestration and biodiversity are significantly lower than if the land was retired from production completely, as in the case of riparian restoration. Furthermore, economic incentive programs can actually create perverse incentives. For example, if there is a subsidy for farmers to implement zero-till on their land, farmers who have previously practiced no-till may make an economically rational decision to cultivate the land to be eligible for the program payment.

Economic instruments that are based on land retirement pay farmers a one-time or an annual payment to remove land from crop production. In existing programs, direct payments are usually designed for select marginal lands or lands that are ecologically sensitive. These programs are intended to compensate farmers for the opportunity cost of foregone crop production. Canada's Greencover Program is an example of such a land retirement program. The precursor to Greencover was the Permanent Cover Program which focused on the retirement of marginal lands (classes 4, 5 and 6 under the Canada Land Inventory) which are those lands that earn the lowest economic returns (Vaiser *et al.* 1996). The Greencover program now focuses on environmentally critical areas and shelter belts for enrolment in the program and farmers receive a one-time payment to convert land to permanent cover (AAFC 2007). A primary objective of the program is to “enhance the health and function” of riparian systems, thus riparian areas are defined as environmentally critical areas under Greencover program. The payment amount does not cover the full opportunity cost of foregone crop production because other economic activities, such as livestock grazing or haying, are still permitted.

An additional private benefit of land retirement programs is that the total amount of area in production is reduced which controls supply. If significant amounts of area are removed from crop production this may contribute to increases in grain prices (Claassen *et al.* 2001). However, while higher prices are beneficial to farmers it is important to note that there will be a negative impact on consumers (Claassen *et al.* 2001).

Land retirement programs are also relatively easy to monitor and enforce thereby reducing the transaction costs. However, land retirement programs are still highly costly because they must cover the cost of production. In general, only where environmental benefits are high should land retirement be implemented (Claassen *et al.* 2001).

Other economic incentive instruments include tradable permits and environmental taxes. Environmental taxes are meant to be a disincentive to environmental harm by charging a per unit tax on practices or emissions that lead to environmental degradation (Weersink *et al.* 1998, Claassen *et al.* 2001). Tradeable emissions permits (e.g. CO_2 equivalents) can allow firms to meet their threshold standard and avoid environmental taxes by purchasing permits from industries that act as net sinks. Practices on agricultural lands that sequester carbon, including wetland restoration, are widely cited to participate in the carbon trade to help stabilize farm incomes. Both emissions trading permits and environmental taxes are representative of the polluter pays principle.

An effective wetland conservation program may be one that is a combination of all of the economic incentive instruments discussed above. For example, only specified wetland influenced areas on the field would be retired in a land retirement program allowing crop production on the remainder of the field. A cost-share program can help cover the costs of restoration while the land-retirement can offset foregone crop production income, thereby encouraging wetland maintenance. Since land retirement programs result in net carbon sequestration, these programs present an opportunity for interplay between private carbon permit trade and publicly funded conservation programs to help reduce publicly funded costs (Feng *et al.* 2004, Feng and Kling 2005). Further discussion on this issue is provided in section 2.4.2 and chapter 3.

While incentive instruments represent useful tools to increase ecosystem goods and service provision on private land, it is difficult to estimate efficient monetary values for economic incentive-based policies. Finding an effecient economic-incentive value is necessary to encourage participation and to help determine total program cost prior to implementation. In addition, the transaction costs of implementation and monitoring and enforcement are high and represent a significant proportion of the total program cost. However, these costs are difficult to define *a priori*. This may represent difficulties in applying for and receiving adequate program funding from the responsible agencies. Miscalculation of total program costs can result in the inability of the program to enrol the desired number of participants or there may be a lack of technical assistance needed to achieve conservation objectives.

In an agricultural context incentive-based environmental protection programs may be an effective replacement for programs that provide subsidies based on crop acreage and yield. Many income supports tied to production have been based on disaster relief. These “ad-hoc” emergency programs are often highly costly and unsustainable (Claassen *et al.* 2001). In addition, international farm trade agreements limit the future abilities of governments to provide production related subsidies. For example, the World Trade Organization Uruguay Round Table Agreement on Agriculture implemented a farm income support ceiling on countries engaging in international trade. However, these income support ceilings exempt “Green Box Payments”; that is payments to farmers for environmental goods and services (Claassen et al. 2001, Feng et al. 2006). As a result of shifting the program subsidies away from crop production to production of environmental goods the public is subsidizing a public good, rather than directly subsidizing farm income with no public return (Lant 1994, Claassen *et al.* 2001, Lant *et al.* 2005). This solution is consistent with the *Pareto improvement* criterion in that those who benefit from wetland preservation would compensate those incurring costs to provide public environmental benefits.

Policies aimed at wetland conservation can be made more effective by including tools to ensure the maintenance of existing wetlands, as these are the most valuable wetland ecosystems, while also encouraging wetland restoration to gain additional benefits (Lovell and Sullivan 2006). The combination of the United States Wetland Reserves Program, which provides a retirement incentive, and the Swampbuster Program, which requires that wetlands be maintained to access any government funding, has been very effective in meeting their wetland conservation objective of no-net loss of wetlands. The results of these American programs show that it is possible to obtain conservation objectives if the political will exists (Heimlich *et al.* 1998 and Claassen *et al.* 2001). However, researchers predict that if incentive-based programs were eliminated in the U.S., the conversion of wetlands to alternative land uses would increase rapidly; this prediction highlights the importance of program continuation (Heimlich *et al.* 1998).

A concern with economic incentives is that offering payment to provide ecological goods and services will detract from feelings of obligation to take care of the environment that we live in. It is possible that farmers have been compensated for providing public goods so often that their willingness to contribute voluntarily is diminishing, this is explained as “conditional cooperation” or “motivational crowding-out” as a result of formal economic incentive (Frey and Oberholzer-Gee 1997, Byrne 2005, Reeson and Tisdell 2006). It may become important in future policies to determine whether it is too late to identify the farmer’s responsibility for environmental protection because of the conditional cooperation problem identified above. If it is too late we may be committed to providing incentives.

The discussion indicates that no single policy instrument will be effective on its own. In terms of wetland policy in the PPR perhaps a combination of compliance and economic incentive programs will be the best way of establishing farmers’ obligations and rights.

2.4. Benefits of Wetlands

Healthy wetland ecosystems provide an array of ecological goods and services to society. These benefits can be divided into two categories 1) market goods and 2) non-market goods. Non-market goods can be further sub-divided into those with use-values and those with non-use or passive-use values (Wilson & Carpenter 1999, Hein *et al.*2006). To further complicate matters, there are ecosystem benefits that provide use values for certain individuals and non-use values for others (Table 2.1). It should be noted that the market benefits for freshwater ecosystems identified in Table 2.1 are mainly limited to larger wetlands, lakes or streams. In the PPR, where the majority of wetlands consist of small isolated basins, we are primarily concerned with non-market ecosystem benefits with the exception of carbon sequestration.

Table 2.1 Benefits associated with freshwater ecosystems (Wilson and Carpenter 1999).

Benefit Class	Benefit Category	Benefit subcategory	Benefits
Market Use	In-water body	Commercial	Transportation
	Withdrawal	Municipal Agriculture Commercial	Drinking water Irrigation Electricity
	Ecosystem	Commercial Potential	Carbon sequestration & greenhouse gas mitigation
Non-Market Use	In-water body	Recreation	Fishing, swimming, boating
	Aesthetic	Enhanced near-water recreation	Hiking, picnicking, photography
	Ecosystem	Enhanced recreation support Other ecosystem services	Wildlife viewing, hunting Erosion control, water quality, flood control, nutrient cycling, biodiversity, carbon storage & greenhouse gas mitigation
Non-Market Non-Use	Vicarious consumption	Significant others – family Diffuse others – public	Any of the above
	Existence or stewardship	Inherent - remote wetlands Bequest –future generations	Any of the above
	Option	Individual risk aversion	Any of the above

There are no market transactions or behavioural trends providing information about the value of non-market ecosystem benefits while the economic values associated with alternative land uses are often much easier to define. For example, the value of potential crop yields or real estate development are easily accessible. As a result, wetland benefits are often underestimated or ignored in traditional cost-benefit analysis (Lant 1994, Heimlich *et al.* 1998, Wilson and Carpenter 1999, Turner *et al.* 2000, Champ *et al.* 2003, Olewiler 2004, Brander *et al.* 2006). The undervaluation of wetland ecosystems in private land management decisions has contributed to the conversion of wetlands into perceived valuable alternative land uses such as agricultural crop production, oil and gas exploration or urban development (Lant 1994, Olewiler 2004). In Canada's prairie region the greatest threat to wetlands continues to be agriculture (NWWG 1988, Wylynko 1999, Huel 2000, Euliss *et al.* 2006, NRC 2007). Without an efficient approach to having wetland benefits considered in farm management decisions the destruction and alteration of these ecosystems will likely continue into the future. Determining the value of wetland ecosystems is an important step in understanding the efficiency of wetland conservation policy which largely depends on non-market valuation techniques.

2.4.1. Non-market Valuation of Wetland Resources

Traditional neo-classical economics attempts to eliminate the market failure associated with non-market, public goods by assigning an estimated dollar value to these goods in traditional benefit-cost analysis. Several attempts at valuing ecosystems through non-market valuation have appeared in the literature since the late 1960s (Hein *et al.* 2006). However, due to the relatively recent development of these methods they are still considered to be flawed and are often criticized in the literature (Hanneman 1994). A major criticism of non-market valuation studies is that they are specific to a particular study area and fixed point in time. The valuation of specific wetland sites cannot be transferred to other sites that have not been studied and it is unknown how findings can be extrapolated to different scales; therefore the results of non-market studies are very limited (Brander *et al.* 2006 and Wilson and Carpenter 1999).

It is difficult to define and provide value estimates for all goods and services provided by wetlands. The consequences of removing wetlands from the landscape are not fully understood and the true cost to society may not be completely realized for many years (Olewiler, 2004). Wetlands are complex ecosystems that can have varying degrees of relatedness to surrounding systems. It is particularly difficult to determine the non-use benefits of wetlands as it is not known exactly what proportion of the population benefits from these non-use benefits and to what degree (Lant 1994, Leibowitz *et al.* 2000, Mitsch and Gosselink 2000, Turner *et al.* 2000, Olewiler, 2004). Errors can also occur as a result of double-counting certain benefits which can lead to inaccurate estimation of wetland values (Hein *et al.* 2006).

Another issue with defining and valuing wetland benefits is that optimizing for one benefit does not necessarily optimize for other benefits and sometimes optimizing for one benefit is at the expense of another (Mitsch and Gosselink 2000). For example, optimizing for recreation activities may be at the expense of wildlife habitat. A partial solution to this problem is to rank the benefits and focus on those that have the greatest benefits for the greatest number of people (Lant 1994, Leibowitz *et al.* 2000). Taking this idea a step further, some researchers select the top ranked benefits and create an index based on a combination of these benefits to allow comparability between sites; this is a similar methodology to that employed in the Conservation

Reserves Program (CRP) in the U.S. (Feng & Kling 2005). The CRP is a land retirement program delivered to farmers in the U.S. The CRP uses an environmental benefits index (EBI) that gives different weights to the environmental benefits and accounts for a cost factor as well to determine the lands that should be targeted for retirement. Land parcels that would result in the highest level of benefits relative to costs based on the EBI are targeted first (Feng & Kling 2005).

The scale of the ecosystem being studied affects the value of its benefits and the ease to which those values can be calculated (Mitsch and Gosselink 2000, Hein *et al.* 2006). For example, valuing the benefits of an entire watershed or landscape will yield a value far greater than if a single wetland is valued. However, it is much more difficult to complete a valuation study at the watershed scale and there is more room for error. Figure 2.1 shows the probable importance of wetland benefits, the benefiting parties and the ease of calculation at different scales.

Scale	Ease of Calculation	Accrual of Benefits	Probable Importance
Population	Easy	Land-owner/local economy	Local economies
Ecosystem		Local/regional public	
Biosphere	Difficult	The world	Life sustaining

Figure 2.1 Ease of calculation, accrual of benefits, and probable importance of values of wetlands at different ecological scales (adapted from Mitsch and Gosselink, 2000).

The most common approach used to estimate values for non-use benefits is contingent valuation (CV). CV is a stated preference method of non-market valuation; it is a direct method of calculation that does not require real market information. There is a great deal of controversy surrounding CV in the economic community due to its creation of hypothetical markets which does not follow the trend of traditional economic analysis which is based on real market evaluation (Hanneman 1994). There is also a great deal of concern in the instrument design and implementation across studies (Lant 1994). For example, the use of closed-ended or open-ended responses to CV questions is highly debated as this can have a significant impact on the end result; however, both methods are commonly used in the literature. Additional criticisms of CV are beyond the scope of this study but they can easily be found in the literature (Hanneman 1994, Carson *et al.* 2001). Despite its criticisms, the ability for CV to capture non-use values (by not requiring market information) and to be applied to a variety of spatial or temporal scales makes it the most appropriate non-market valuation method for valuing wetlands (Lant 1994).

The contingent valuation methodology uses surveys to directly quantify people's willingness to pay (WTP) for a particular environmental good or willingness to accept (WTA) to provide an environmental good. For example, a CV survey usually outlines a proposed policy such as a wetland habitat preservation program. Following a description of the program, a WTP question may look like the following:

> "With the implementation of the proposed policy you would have to pay an annual conservation payment into the foreseeable future, what is the highest amount that you would pay and still vote in favour of the policy?"

Alternatively, a WTA question would ask those providing the environmental benefit; what is the minimum compensation payment amount that you would require to vote in favour of the policy? The responses may be open ended, where the respondent makes up their own value, or they may be closed-ended, where the respondent either has to choose from a range of values or simply votes yes or no to a single value provided. By changing the quality or quantity of an environmental good outlined by the policy proposal there is an associated change in utility or welfare to all stakeholders. Depending on the environmental change outlined by the policy proposal, stakeholders choose either the WTP or WTA amount to improve or maintain their current welfare status.

Despite the criticisms and problems with non-market valuation, particularly CV, most researchers agree these studies show that society does attach a significant positive value to wetland ecosystems (Wilson and Carson 1999). However, caution must be exercised in the use of non-market valuation to help achieve wetland conservation objectives. If public values for ecological goods and services are determined, there is a need to transfer that value to private land owners so that there is an incentive for them to provide wetlands (Lant 1994). In the absence of institutions and measures to transfer public value to the private landowner, wetlands will continue to decline unless farmers themselves recognize an inherent value in these ecosystems (Amigues *et al.* 2002).

Non-market valuation can help determine the level of payment needed to encourage farmers to conserve wetland ecosystems. In the past, contingent valuation studies have most often measured willingness to pay or compensating surplus (Champ et al. 2003). Difficulties in defining these values have raised concerns about the ability of these non-market valuation studies to determine the benefits provided by wetlands. Without this information, we lack the understanding of what level of wetland preservation would maximize net public and private benefits (Lant 1994).

In terms of public value, it is more useful to employ an ecological measure that defines the quantity and quality of the ecosystem required to deliver an acceptable level of environmental goods to society. The economic value of use is then the minimum willingness to accept amount for compensation in order for landowners to provide the established acceptable level of environmental benefits. The WTA represents the financial incentive value required by landowners to provide wetlands and the associated environmental benefits on the landscape. The WTA measure is accurate because there is a defined population and the compensation measure should be closely associated with the cost of restoration and maintenance and the value of the land in the best alternative land use (Amigues *et al.* 2002).

Methods of transferring public values to landowners may come in the form of markets or through publicly funded conservation programs. Government intervention through conservation program payments should be used with caution to avoid "conditioned cooperation". Conditional cooperation refers to farmers becoming accustomed to being financially compensated to manage for the environment, thus reducing the likelihood that they will provide environmental goods and services voluntarily (Frey and Oberholzer-Gee 1997, Reeson and Tisdell 2006). It is also recommended that government intervention through conservation program payments be a last resort to reduce public costs. Therefore, it is important to understand how markets can be utilized to achieve conservation goals, which is discussed further in the next section.

2.4.2. Market Value – Carbon Sequestration

Due to increasing attention paid to global climate change, the focus of market benefits derived from prairie pothole wetland ecosystems in this study is carbon sequestration. Private carbon markets such as the Chicago Climate Exchange (CCX 2008) were recently developed following the recognition of biological carbon sinks as an accepted mechanism for countries to meet their GHG emission reduction commitments under the Kyoto Protocol (IPCC 2001).

Since the industrial revolution there has been a 31% increase in atmospheric CO_2 which is believed to be largely responsible for global climate change (IPCC 2001). Conversion of grasslands and wetlands to cropland has released more than 30% of the original soil organic carbon to the atmosphere (Liebig *et al.* 2005). Conversion to cropland has also affected atmospheric composition through reductions in ability of soils to sequester carbon and increases in other greenhouse gas emissions such as nitrous oxide (N_2O) and methane (CH_4) (Bridgham *et al*. 2006 and Liebig *et al.* 2005). It has been estimated that agriculture production has been responsible for up to 20% of the increases in global greenhouse gas (GHG) emissions (IPCC 2001). As a result, farm management changes that can potentially lead to increases in soil organic carbon stocks have been widely cited as a potential strategy for the PPR to help mitigate climate change but up until recently the majority of this research has focused on the implementation of zero till, permanent cover and fertilizer management practices (Bruce *et al.* 1998, Dumanski *et al.* 1998, Janzen *et al.* 1998, Lal and Bruce 1999, McConkey *et al.* 2000, McCarl and Schneider 2001, Smith *et al.* 2001, VandenBygaart *et al.* 2003, Boehm *et al.* 2004, Dumanski 2004, Lal 2004, Desjardins *et al.* 2005, Liang *et al.* 2005, Liebig *et al.* 2005, Pretty and Ball 2005, Hutchinson *et al.* 2007). Within the last 5 years there has been growing recognition of the potential of wetlands as net carbon sinks in agricultural landscapes and wetland restoration has been cited as a carbon sequestration strategy (Slobodian et al. 2001, Dumanski 2004, Pennock 2005, Bedard-Haughn *et al.* 2006[a], Bedard-Haughn *et al.* 2006[b], Bridgham *et al.* 2006, Euliss *et al.* 2006, Müller *et al.* 2006, Pennock 2007). Unfortunately there has been little integration between agriculture and wetland carbon sequestration research. It is not uncommon for agricultural studies to ignore wetlands and vice versa. Furthermore, riparian buffer areas are often ignored completely as agricultural researchers often assume that they are part of the wetland and wetland researchers often assume that they are part of the upland. This greatly limits the true understanding of carbon sequestration on an agricultural landscape.

PPR wetlands can account for up to 23% of the agricultural landscape and wetland soils may store up to twice as much carbon as the surrounding agricultural land (Euliss et al. 2006). Carbon sequestration is achieved when plants uptake CO_2 from the atmosphere and incorporate it into biomass which is then incorporated into the soil. In wetlands soil organic carbon (SOC) is also sequestered by erosional deposition (sedimentation). It has been suggested that SOC gains in wetlands are more stable than their upland counterparts because of aggregate formation and burial of SOC below the level of active decomposition (Bedard-Haughn *et al.* 2006[b]).

The carbon sequestered by implementing environmentally beneficial management practices requires the investigation of any potential GHG emissions that may negate the SOC benefits. Methane (CH_4) and nitrous oxide (N_2O) are currently the main sources of greenhouse gases in

Canadian agriculture (Smith *et al.* 2001). The relative impact of these greenhouse gases as a result of wetland and riparian vegetation restoration are discussed in greater detail below.

Methane has 23 times the global warming potential of CO_2 and is produced under anaerobic conditions which are prevalent in wetlands (IPCC 2001). Additionally, methane emissions from wetlands are controlled by water chemistry, in particular sulfate (SO_4^-). In the reduction sequence that leads to methane production, sulfate-reducing bacteria actively out-compete methane-producing methanogens. Thus, with sufficient SO_4^- in the water and sediment column the redox reaction required for methane production is not achieved (Schönheit et al. 1982). The vast majority of semi-permanent and permanent wetlands in the PPR are dominated by SO_4^- anions so methane production is negligible. Methane is emitted at relatively high rates from ephemeral wetlands; however, methane is produced regardless of the land use and restoring native vegetation is unlikely to have an effect on the net methane emissions (Pennock 2007[a], Pennock 2007[b] and Pennock and Elliot 2007).

Nitrous oxide has 296 times the global warming potential of CO_2 (IPCC 2001) and in agricultural soils emissions depend on soil moisture conditions (Pennock and Corre 2001 and Yates *et al.* 2006). If water is maintained in the basin throughout the season N_2O production is minimal. Nitrous oxide production may occur in riparian areas and basins when water is drawn down below sediment level; however, emissions are considered to be minor in comparison to the SOC sequestration rates observed on the landscape (Bedard-Haughn et al. 2006[a], Pennock 2007[a], Pennock 2007[b], Pennock and Elliot 2007). Based on these previous studies it is apparent that the land use changes involved in the restoration of riparian vegetation is not deemed to have a significant effect on CH_4 and N_2O emissions in the PPR.

The SOC sequestration potential of a given area depends on two overarching controls: 1) the initial SOC content prior to carbon sequestration practices and 2) the rate of C input under the prevailing environmental conditions (Janzen *et al.* 1998, VandenBygaart *et al.* 2003, Pennock 2005). Although the focus of this study is largely on wetlands and riparian areas it is recognized that these elements occur within a larger agricultural landscape matrix. To determine the soil organic carbon sequestration potential of an agricultural field, the cropped areas must be considered as well. Soil organic carbon sequestration may be strongly influenced by landform while crop type exerts little or no influence (Pennock and Corre 2001).

Realistic carbon sequestration co-efficients (rate of C input) are needed to determine the potential carbon that can be stored over a specified time period. These co-efficients are needed for all of the landscape elements under the different land-use options. To determine the rate of C input by no-till under the prevailing environmental conditions, a review of the relevant literature is summarized in Table 2.2. There is a general consensus that SOC sequestration by no-till can be sustained for 20-50 years before a steady state is reached (Dumanski *et al.* 1998, Boehm *et al.* 2004, Desjardins *et al.* 2005).

Table 2.2 Carbon sequestration co-efficients for cropland under no-till.

Region	Annual C Sequestered (Mg ha^{-1} yr^{-1})	Regional Mean (Mg ha^{-1} yr^{-1})	Source
Brown Soil Zone	0.08		Smith *et al*. 2001
	0.10		Liang *et al*. 2005
	0.10		McConkey *et al*. 2000
	0.13		Vandenbygaart *et al*. 2003
	0.20		Boehm *et al.* 2004
		0.12	
Dark Brown Soil Zone	0.14		Liang *et al.* 2005
	0.15		Smith *et al*. 2001
	0.20		Boehm *et al*. 2004
	0.30		McConkey *et al*. 2000
	0.37		Vandenbygaart *et al*. 2003
		0.23	
PPR/Western Canada	0.20		Bruce *et al.* 1998
	0.27		Liebig *et al.* 2005
	0.2-0.3		Euliss *et al.* 2006
	0.2-0.35		Desjardins *et al.* 2005
	0.0-0.4		Hutchinson *et al.* 2007
		0.24	

Few studies have investigated the potential of pothole wetlands and riparian areas to sequester carbon. Bridgham *et al.* (2006) estimated that carbon could be sequestered in freshwater prairie wetland sediments at rates ranging from 0.17-1.85 Mg ha^{-1} yr^{-1} but these estimates were presented with a very high level of uncertainty. Euliss *et al.* (2006) found that restored wetland soils can sequester up to 3.05 Mg C ha^{-1} yr^{-1}. Pennock and Elliot (2007) indicated that when cropland was restored to permanent cover or riparian vegetation SOC could be sequestered at an average rate of 1% per year over a 20 year period based on the initial carbon stores (Table 2.3). It is assumed that existing riparian and basin areas are at a steady state so no additional C is sequestered by maintaining these areas but they still represent a large carbon store on the landscape (Bedard-Haughn *et al*. 2006[b]).

Table 2.3 Annual carbon sequestration co-efficients for restoring permanent vegetation in wetland basin, riparian and upland areas.

Region	Basin[ab] (Mg C ha^{-1} yr^{-1})	Riparian[ac] (Mg C ha^{-1} yr^{-1})	Upland[ad] (Mg C ha^{-1} yr^{-1})
Brown Soil Zone	0.80	0.77	0.52
Dark Brown Soil Zone	1.07	1.03	0.70

[a] Average annual SOC increase based on a 1% increase each year for 20 years (Pennock and Elliot 2007).
[b] Depression elements.
[c] Convergent footslope elements.
[d] Average of shoulder, backslope & divergent footslope elements.

A review of the literature has thus suggested that restored wetlands represent the greatest potential for carbon sequestration (per hectare) on agricultural fields and a policy that targets these areas for restoration and conservation may be an effective strategy for carbon sequestration (Bedard-Haughn *et al.* 2006[b]). However, wetland influenced areas converted to cropland are often the most productive areas on the field in terms of crop production due to greater moisture availability, organic matter, N mineralization and favorable textural composition (Pennock *et al.* 1994, Jowkin and Schoenau 1998, Si and Farrell 2004). Pennock *et al.* (2001) found that canola yields in the black soil zone were 1.47 times greater in the depressional elements than the field mean. Jowkin and Schoenau (1998) found that spring wheat yields in footslope elements in the brown soil zone were 1.15 -1.29 times greater than the field mean. This represents a positive relationship between land productivity and carbon sequestration potential which is problematic in terms of developing a cost effective policy.

In 2007 and early 2008 the value of carbon contracts on the CCX ranged from \$1.00 to \$5.00 CAD per tonne CO_2 equivalent (CCX 2008), which represents approximately \$3.00 to \$20.00 CAD per hectare in the brown and dark brown soil zones in the PPR based on the mean carbon sequestration rates found in Table 2.3. Thus, the value of carbon contracts is considerably less than the mean agricultural production value on the same land which ranges from \$74 to \$117 per hectare (Table 3.4). Thus, the opportunity cost associated with wetland restoration *and* maintenance is likely to greatly exceed the value of carbon (Feng and Kling 2005). Another issue is that intact wetlands on the landscape represent large carbon stores (Bedard-Haughn *et al.* 2006[b]). Existing carbon stores are not eligible for trade on the private carbon market but there is still a need to maintain these stores to help mitigate climate change (Pretty and Ball 2005). It is also unlikely that individual producers will be able to sequester enough carbon to participate in carbon markets without the use of a carbon aggregator. The above discussion indicates that carbon markets alone may not be sufficient to entice farmers to restore and conserve wetland influenced areas. Fortunately, there is potential for interplay between private carbon markets and government funded conservation programs to achieve conservation objectives.

2.5. Targeting Considerations for Wetland Policy

There are different targeting strategies to achieve environmental benefits. For example, targeting for benefits alone enrolls land with the highest per-unit benefit regardless of cost. Traditionally, environmental groups show a preference for benefit targeting (Wu *et al.* 2001). But, research has indicated that the more stringent the environmental goals the more steeply the cost rises (Khanna *et al.* 2003). Cost targeting enrolls land of the lowest cost regardless of the environmental benefits; this strategy is typically favored by private land owners but is largely considered socially inefficient (Wu *et al.* 2001). The socially optimal targeting strategy may be benefit-cost targeting which targets land based on a benefit to cost ratio.

With limited public funds, targeting is used to find the least cost way of meeting clearly defined environmental objectives within budget (Wu *et al.* 2001, Khanna *et al.* 2003, Zhao *et al.* 2003, Yang *et al.* 2003, Yang and Weersink 2004, Yang *et al.* 2005, Marshall and Homans 2006). In addition, designing an efficient wetland policy relies on strategies that reflect farmer preferences so the policy is readily adopted (Lovell and Sullivan 2006). Thus, it is important to determine how to target policy on the landscape by considering environmental objectives and cost-effectiveness to meet objectives within the context of social and farmer preferences.

An important consideration for wetland policy is the correlations between benefits and agri-economic costs (Figure 2.2). When environmental benefits are negatively correlated to agri-economic costs the areas that cost the least are also more likely to offer larger environmental benefits. The winners are easily capable of compensating the losers which results in a classic "win-win" situation for multiple stakeholders. On the other hand, when costs and benefits are positively correlated, the least cost targeting strategies are also more likely to offer fewer benefits. When benefits and costs are positively correlated it is a "win-lose" situation and trade-offs exist between private economic costs and social environmental benefits, thus, there are vast differences in the policy preferences of stakeholders (Wu *et al.* 2001).

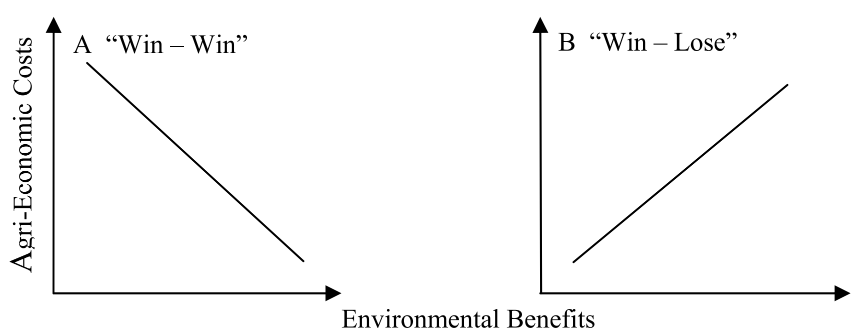

Figure 2.2 Possible relationships between agri-economic costs and environmental benefits; A negative relationship; B positive relationship (adapted from Pretty and Ball 2005).

2.5.1. Targeting for Benefits vs. Management Practices

It is recommended that policy strategies be based on the most cost-effective strategy to meet clearly defined environmental objectives within given budget constraints (Wu *et al.* 2001, Khanna *et al.* 2003, Zhao *et al.* 2003, Yang *et al.* 2003, Yang and Weersink 2004, Yang *et al.* 2005, Marshall and Homans 2006). Managing for environmental benefits can be achieved through targeting specific benefit goals or management practice goals (McCarl and Schneider 2001, Zhao *et al* 2003). Managing for multiple co-benefits simultaneously has been shown to be complicated and less efficient so it becomes essential to target an effective environmental policy to the most important benefits or management practices (Lant 1994). For a wetland conservation program that plans to utilize the carbon market, the question arises; should the policy be targeted to a benefit such as carbon sequestration or wetland management practices? Although it is generally assumed that environmental co-benefits are positively correlated, optimizing for single benefit goals can result in very different allocations of land use and co-benefits on the landscape (Mitsch and Gosselink 2000, McCarl and Schneider 2001, Zhao *et al.* 2003, Feng and Kling 2004, Feng et al. 2005). Thus, it is important to understand the correlations that exist among different environmental benefits.

The initial focus for policy design is on carbon sequestration benefits due to the considerable attention it has been given lately as a climate change mitigation strategy and the possible use of carbon markets to offset publicly funded program costs. In addition, management practices that lead to carbon sequestration on agricultural fields are widely recognized as providing significant environmental co-benefits (positive externalities) such as erosion reduction, wildlife habitat and biodiversity (Zhao *et al.* 2003, Dumanski 2004, Feng and Kling 2005, Feng *et al.* 2005, Lambert *et al.* 2006).

Programs that are designed specifically for a single benefit, such as carbon sequestration, will use least cost management practices to achieve that particular goal. Although the co-benefits of carbon sequestration are significant, they are primarily external to the farmer so these values will not be incorporated into management decisions. Thus, the cost-effectiveness of targeting for carbon sequestration benefits in a wetland conservation policy is dependent on the relationship between soil productivity and soil carbon sequestration on the landscape. The discussion in section 2.4.2 indicates that a positive relationship exists between the soil productivity and carbon sequestration in wetland influenced areas. Therefore, in terms of carbon sequestration farmers will readily adopt management practices that are more cost-effective such as zero-till, nutrient management and crop rotation to meet carbon sequestration goals while practices associated with greater costs such as foregone crop production associated with riparian areas are unlikely to be adopted even though the co-benefits would be greater (Dumanski 2004, Lambert *et al.* 2006). Furthermore, even when financial assistance is provided for carbon programs that require land retirement, in general, only large farms participate and they enrol only a relatively small proportion of their farm in the program (Lambert *et al.* 2006).

From a wetland policy stand-point, it is likely more efficient to design a policy that focuses on management practices that result in the maintenance and restoration of wetlands to achieve multiple co-benefits rather than requiring certain levels of carbon sequestration. Furthermore, McCarl and Schneider (2001) and Zhao *et al.* (2003) found that policies with management practice goals often have a higher level of success in encouraging participation and ultimately achieving net environmental benefits than policies that focused directly on benefit goals.

2.5.2. Spatial Targeting

If wetland restoration and conservation is the management goal, understanding wetland ecosystem function is essential to determine the proper spatial units to be considered in economic analysis and in policy. For example, in temperate regions, it is suggested that 3-7% of the landscape be composed of wetlands to provide adequate environmental services (Mitsch and Gosselink 2000). It is also important to determine how to target policy on a local scale to meet landscape ecosystem objectives.

Landscape function is defined as the net effect of all ecosystems on the landscape, including synergistic effects, and the value of individual wetlands is dependent on where they are in the landscape and how closely associated they are with other systems (Leibowitz *et al.* 2000, Mitsch and Gosselink 2000). Thus, the benefits of a single wetland or single parcel of land may be negligible but it can make important contributions on the landscape by creating and maintaining connectivity. This suggests that it is more beneficial to have wide participation on the landscape rather than maximizing benefits on a few parcels. Parkhurst and Shogren (2007) suggest that providing bonuses to enrol land that is in close proximity to other conserved parcels of land can be important in ensuring contiguous habitat. However, coordination in this type of program requires expertise and farmers not familiar with this type of system are unlikely to adopt it. Ultimately, participation in conservation programs is still affected by initial beliefs and direct financial assistance (Parkhurst and Shogren 2007).

Developing efficient financial incentive levels for wetland conservation policy is usually achieved by targeting watersheds as a single spatial unit (Lant *et al.* 2005, Lovell and Sullivan 2006). However, in the PPR many wetlands do not contribute to a larger watershed but it is still important to improve and maintain connectivity of native ecosystems on the landscape. In this case it may be more suitable to base spatial units on soil, vegetation and climatic characteristics. For example, the spatial units could be based on soil zones, ecoregions or soil polygons, which are composed of relatively homogeneous soils and similar environmental characteristics.

At the local scale it is important to determine which wetlands on the landscape should be targeted and the width of riparian area or buffer strip that needs to be provided to achieve essential ecosystem functions for individual wetlands. Prairie wetlands represent a variety of different ecosystems which are effectively described by the Stewart and Kantrud (1971) wetland classification scheme (Table 2.4). The wetland classification scheme is based on permanency of water in the basin throughout the growing season; greater water permanency indicates a greater number of vegetation zones within a particular wetland and generally greater biodiversity. However, maximum biodiversity is achieved on the landscape by providing a variety of different ecosystems which includes both permanent and seasonal wetlands.

Table 2.4 Classification of freshwater prairie wetlands (Stewart and Kantrud 1971).

Class	**1**	**2**	**3**	**4**	**5**
Water Residence	**Ephemeral**	**Temporary**	**Seasonal**	**Semi-Permanent**	**Permanent**
Vegetation Zones	wetland low prairie	wetland low prairie wet meadow	wetland low prairie wet meadow shallow marsh	wetland low prairie wet meadow shallow marsh deep marsh	wetland low prairie wet meadow shallow marsh deep marsh open water

Due to the high degree of physical and chemical variability in wetlands across the PPR the benefits are also highly variable across wetlands. In general, the wetlands that remain on agricultural landscapes are those that are less suitable for crop production or are too difficult or expensive to drain/cultivate. These are typically permanent or saline wetlands (NWWG, 1988). In general, due to the nature of wetlands in Saskatchewan's PPR, wetland restoration can often be achieved with the elimination of cultivation from wetland influenced areas on the landscape. In other words, active restoration involving the physical construction of dams or barriers is not usually required for restoration. In the case of permanent wetlands, the majority of basins still remain intact on the landscape but their margins, or riparian areas, have been encroached upon by cultivation which limits the wetland's ability to function. Restoration and enhancement of these permanent wetlands can often be achieved by simply expanding the perennially vegetated riparian areas surrounding the existing basins to reflect the true influence of wetlands on the landscape. Many of the seasonal wetlands have been cultivated and cropped in their entirety, essentially eliminating their presence on the agricultural landscape. The restoration of these seasonal wetlands would depend on cessation of cultivation through both their basins and riparian areas. It is often perceived that small wetlands provide negligible benefits and therefore there is no need to conserve them; however, conservation of wetlands should follow the law of scarcity, when fewer exist they should be viewed as more valuable and be incorporated into policy objectives (Mitsch and Gosselink 2000).

There is not a general consensus among scientists regarding a standard riparian zone width required for healthy wetland functioning in the PPR. However, few examples in the literature indicate that a riparian buffer width of 10-30m is usually required for proper functioning depending on the size and class of wetland (Huel 2000, Rickerl et al. 2000, Phillips et al. 2005). There is some discussion over the use of precision riparian buffers, which are based on physical characteristics of each individual wetland such as elevation, soil electrical conductivity and vegetation, as opposed to the use of fixed-width riparian buffers. Since precision buffers are based on the actual physical conditions of each wetland, they represent each wetland's true influence on the landscape. Therefore, several researchers support the use of precision conservation buffers because they are biologically optimal and may be more cost-effective if the total area that needs to be preserved under a precision buffer scenario is considerably less than for a fixed buffer width scenario (Yang *et al.* 2003, Yang and Weersink 2004, Dosskey *et al.* 2005). However, the implementation of a precision buffer program design can be more costly than a fixed buffer due to the transaction costs associated with the technical equipment and expertise required to establish precision buffer areas. Dosskey *et al.* (2005) argue that the higher transaction costs in a precision buffer program can be offset by eliminating unnecessary costs associated with retiring land that can still reasonably be in crop production. However, an issue arises with who is responsible for the costs associated for this type of program. Most farmers cannot afford to implement a conservation buffer design on their fields and do not have technical capabilities. On the other hand, a government delivered extension program that provides this expertise is also costly. Another issue with a precision riparian approach is that many farmers do not respond well to irregular patterns in their fields which is viewed as unsightly and inconvenient (Dosskey *et al.* 2005).

It has been widely suggested that environmental policies that use land retirement as a tool should focus first on fields with the lowest marginal cost and then move up until environmental objectives are met. Payments made on a per unit benefit/cost basis capture spatial heterogeneity, and land with the highest benefit per dollar should be targeted first which makes it very important to determine early on which benefit(s) are being optimized (Leibowitz 2000, Khanna *et al.* 2003, Feng and Kling 2004 and Feng *et al.* 2005). It is also important to remember that for a wetland conservation program we are not necessarily targeting entire fields for retirement but wetland elements within the fields.

Transaction costs should also be considered in policy design as they can make a significant contribution to the overall program cost. Allowing too much variation within a program usually imposes increased administrative costs and a requirement for technical expertise. For example, a precision buffer wetland conservation program may be more cost-effective in terms of program payments but the increased transaction costs may negate any of the benefits achieved with precision conservation program. In addition, site specific programs are difficult to implement because they are viewed as unfair and they pose political and administrative difficulties (Khanna *et al.* 2003, Yang *et al*. 2003).

There also needs to be consideration for the output effects of spatially targeted financial incentive schemes. If only land that is in current production is targeted then there is a perverse incentive to put land that is already idle back into production to offset the cost of retiring other lands (Wu *et al.* 2001). This has important policy implications for wetlands in the PPR; to avoid such perverse incentives a policy where both restored and existing wetlands areas are eligible for enrolment in the conservation program may be necessary.

2.5.2.1. Climate change impacts on wetlands

An often overlooked aspect of spatial targeting of environmental policies is the effect of climate change on the benefits that can be achieved under different targeting scenarios. In the previous section seasonal wetlands were identified as valuable elements on the landscape that could potentially be targeted for restoration and conservation initiatives. However, Larson (1995) found that climate explains 60% percent of the variation in basin numbers, water levels and vegetation structure in the PPR. Climate change is likely to result in many seasonal wetlands drying up for longer periods of time than would be expected with the previously normal climate cycles or they may dry up permanently (Larson 1995, Poiani *et al.* 1996, Johnson *et al.* 2005). This may negate some of the important benefits that conservation programs strive toward including wildlife habitat, biodiversity and carbon sequestration. For example, prime migratory bird habitat is found in wetlands that have a ratio of emergent vegetation cover to open water approaching 1:1, as open water provides food and breeding habitat while emergent vegetation provides cover and nesting habitat (Poiani 1993). If open water is eliminated from these wetlands entirely, there will be too much vegetation cover to be utilized by migratory birds (Johnson *et al.* 2005). Less available moisture would also reduce overall biomass production and potentially reduce the amount of soil organic carbon that can be sequestered.

Modelling scenarios of climate change show that wetlands in the dry areas of Alberta and Saskatchewan will be the most highly impacted ecosystems (Johnson *et al.* 2005). In addition, semi-permanent and permanent wetlands that have previously held water throughout the spring and early summer seasons are in danger because they could potentially dry up early enough in the season to be cultivated for crop production. Furthermore, increasing grain prices, partially due to bio-fuel demands, are driving farmers to maximize the amount of area that they can put into production. This indicates that not only should wetland conservation programs target semi-permanent and permanent wetlands but also focus more on the wetter, fringe areas of the PPR because greater benefits can be accrued (Johnson *et al.* 2005). Unfortunately, these wetter, fringe areas are also the most productive areas for agriculture where more than 90% of the wetlands have already been drained or altered (Tiner 2003). The restoration costs in these areas are much greater than in drier regions due to greater soil productivity and more favourable environmental conditions for crop production, thereby making the targeting of wetter regions prohibitive from a cost perspective. There are also concerns with program equity in that policy makers are hesitant to favour farmers in one region over another.

2.6. Social vs. private planning horizon

Management decisions and policies that are based on short and long-term models result in very different landscape patterns (Marshall and Homans 2006). Farm management is based on economic efficiency and maximizing farm income in the current time period and immediate future (e.g. 1-5 years). It is likely that current investments in ecological capital would reduce farm income in the short-term but these investments may actually increase farm income in future time periods (Lant *et al.* 2005). However, due to volatile markets and income instability in agriculture, risk adverse farmers will try to maximize their net benefits in the current time period while future time periods are largely ignored. It has been widely recognized in the economic literature that private land owners will not act altruistically for the sake of environmental protection and public benefits if it does not improve their immediate net private benefits (Danielson & Leitch 1986, Turner *et al.* 2000, Lant *et al.* 2005). The current market trend of increasing grain prices in the PPR, in-part due to growth in the bio-fuels industry, may bring even more marginal wetland areas into production for short-term economic gain. Furthermore, the 2006 Statistics Canada Census of Agriculture reported that the farm population in Saskatchewan is aging with an uncertainty as to how long that they will continue to farm and many of them without successors; this indicates that there is little or no inherent value to conserve or manage for future generations.

Similar to farmers, public policy makers also have a relatively short-term time horizon with their main objective being re-election after 4-5 years (Fuguitt and Wilcox 1999). The relatively short-term planning horizon of individual landowners and politicians contrasts with social values. Society generally believes that it has a responsibility to ensure that the welfare of both current and future generations are taken into account in the allocation of resources (Fuguitt and Wilcox 1999). The economic value gained in the short-term may be great but it is finite (e.g. 50-100 years) while the benefits of wetland ecosystems are accrued in perpetuity. However, if wetland destruction continues for short-term economic gain the effects of such projects may be irreversible and wetland values may be lost indefinitely (Mitsch and Gosselink 2000).

Many of the current conservation programs that were discussed previously have commitment periods of 10 years (e.g. Conservation Reserves Program in the U.S. and the Greencover Program in Canada). While these programs may already extend over a greater period of time than most farmers would traditionally plan for, the extent of environmental benefits that can be realized in that time is only a fraction of their full potential. For example, landowners in the CRP are eligible to put their land back into production after 10 years; if this land reverts to crop production the benefits gained from the program are essentially eliminated. Therefore, although programs have to be designed with a finite time period that is suitable for farm management, there is also a need to re-negotiate contracts after the program period and encourage farmers to maintain their reserved lands so that benefits can be realized in the long term.

3.0 ECONOMIC INCENTIVES IN WETLAND POLICY: AN EMPIRICAL INVESTIGATION OF CARBON-BASED PAYMENT AND CONSERVATION PROGRAM PAYMENTS

3.1. Introduction

Saskatchewan's agricultural region is primarily made up of the previously glaciated area known as the Prairie Pothole Region (PPR) (Figure 1.1). Wetlands historically made up 23% of the land area in the PPR but it is estimated that 50 -70% of these wetlands have been lost or altered primarily because of agricultural drainage and cultivation (NWWG 1988, EC 1991, Wylynko 1999, Euliss *et al.* 2006). Along with the destruction of native habitat, the conversions of grasslands and wetlands to cropland have reduced the capabilities of soil to sequester carbon and have caused the released of up to 35% of the soils' original carbon stores as carbon dioxide (CO_2) into the atmosphere, contributing to global climate change (Gregorich *et al.* 1995, Dumanski *et al.* 1998, Janzen *et al.* 1998, Smith *et al.* 2001, VandenBygaart *et al.* 2003, Liebig *et al.* 2005, Bridgham *et al*. 2006).

With growing concern about climate change and Canada's ratification of the *Kyoto Protocol* in December 2002, there has been increasing attention paid to the potential of wetlands and agricultural lands to help mitigate climate change by restoring and maintaining carbon stores. There is also increasing recognition of other benefits associated with wetlands, strengthened by Canada's international commitments under multilateral environmental agreements such as the *Ramsar Convention* for wetland mitigation, the *Migratory Birds Convention Act* for the protection of wildlife habitat and The *Convention on Biological Diversity*. These treaties along with changing social attitudes towards managing for the environment have created a public demand for policies that protect wetlands ecosystems (EC 1991).

Economists often cite the loss of wetlands on the prairie landscape as a market failure due to the inability of farmers to capitalize on the social benefits provided by wetlands. With little inherent financial motivation for farmers to provide ecological goods and services on the landscape formal incentives have become an important policy tool to encourage farmers to manage for the environment. Developing publicly funded incentive programs that focus on the restoration and conservation of wetlands can result in multiple environmental benefits, such as carbon sequestration, wildlife habitat and biodiversity, that can help Canada honour its commitments to international environmental treaties.

This study investigates land use allocation and the carbon sequestration potential of agricultural landscapes in the PPR. First, the characteristics of farmers that may influence their participation in environmental conservation are investigated, in particular for maintaining healthy wetland and riparian ecosystems on agricultural land, both in the absence and presence of financial incentives. An empirical investigation is also conducted on the interplay between free market carbon-based payments and publicly funded conservation programs as policy tools to encourage farmers to restore and maintain wetland and riparian areas on privately owned agricultural land.

3.2. Carbon Sequestration Potential of Saskatchewan Agricultural Landscapes

Under the Kyoto Protocol, biological carbon sinks have been accepted as mechanisms for countries to meet their greenhouse gas (GHG) emission reduction commitments. As a result of this decision, management changes such as zero-till and wetland restoration, which can potentially lead to increases in soil organic carbon (SOC) stocks, have been widely cited as strategies to help mitigate climate change (Slobodian *et al.* 2001, Dumanski 2004, Pennock 2005, Bedard-Haughn *et al.* 2006[a], Bedard-Haughn *et al.* 2006[b], Bridgham *et al.* 2006, Euliss *et al.* 2006, Müller *et al.* 2006, Pennock 2007). However, there has been little integration between agricultural and wetland research on carbon sequestration.

Carbon sequestration is achieved when plants uptake carbon dioxide (CO_2) from the atmosphere and incorporate it into biomass that is then incorporated into the soil. Historically, the wetland and grassland ecosystems in the PPR were believed to be in a steady state with the carbon stock in the soil at its maximum carbon storage potential. The conversion of these native ecosystems to annual cultivation resulted in increased decomposition rates and a resulting net decrease of SOC stocks in agricultural soils and a contribution to increased atmospheric concentration of CO_2.

Canadian agricultural lands are estimated to have lost 15-35% of their pre-settlement SOC stores (Gregorich *et al.* 1995, Dumanski *et al.* 1998, Janzen *et al.* 1998, Smith *et al.* 2001, VandenBygaart *et al.* 2003). In the PPR it is estimated that wetlands can account for up to 23% of the agricultural landscape area and wetland soils could store up to twice as much carbon as the surrounding agricultural land as a result of relatively large accumulations of biomass and also erosional deposition (sedimentation) from the surrounding uplands (Euliss *et al.* 2006). In addition, SOC gains in wetlands may be more stable than their upland counterparts because of aggregate formation and burial of SOC below the level of active decomposition (Bedard-Haughn *et al.* 2006). Thus, the carbon storage potential of restored wetland areas can make significant contributions to the overall carbon storage potential of these agricultural landscapes.

The carbon sequestered by implementing environmentally beneficial management practices, such as wetland vegetation restoration, requires an investigation of the GHG emissions that may offset SOC benefits. Methane (CH_4) and nitrous oxide (N_2O) are generally the greenhouse gases of greatest concern in Canadian agricultural landscapes (Smith *et al.* 2001). Research conducted by Bedard-Haughn *et al.* (2006) and Pennock *et al.* (2007) suggests that emissions of CH_4 and N_2O due to restoration of riparian vegetation are negligible relative to the total amount of carbon that is sequestered. Emissions of CH_4 and N_2O are largely controlled by hydrological conditions, since the restoration of permanent vegetation is not deemed to significantly impact the hydrology of these restored areas, emissions are also not greatly influenced by this land use change. For this reason, only the SOC sequestration potential of wetland areas was considered in the total carbon balance for this study. An empirical investigation of the carbon sequestration potential of agricultural fields, including wetlands, is included in this study to determine the potential value of carbon that can be traded on carbon markets.

3.3. Materials and Methods

3.3.1. Site Description

The two study regions used in this research were selected to represent distinct agricultural regions within the prairie pothole region in Saskatchewan. The study regions were centred on Statistics Canada Census Agriculture Regions (CAR) 3AN and 8B (Figure 3.1). A case study farm was also selected for both regions for a more in depth analysis of wetland conservation program designs on specific landscapes. The 65 ha McInnis (MCI) site was located in 3AN and the 66 ha St. Denis National Wildlife Area (SDNWA) site was located in 8B. These study sites were part of a larger collaborative study focused on understanding the role of wetlands, riparian zones and land management in GHG dynamics within agricultural landscapes, funded by Ducks Unlimited Canada and Agriculture and Agri-Food Canada These sites were chosen for this portion of the study based on their similar management history which facilitates comparisons between regions. Both sites were originally broken in the early 1920s and were conventionally cropped until no-till, continuous cropping was employed in the mid 1990s.

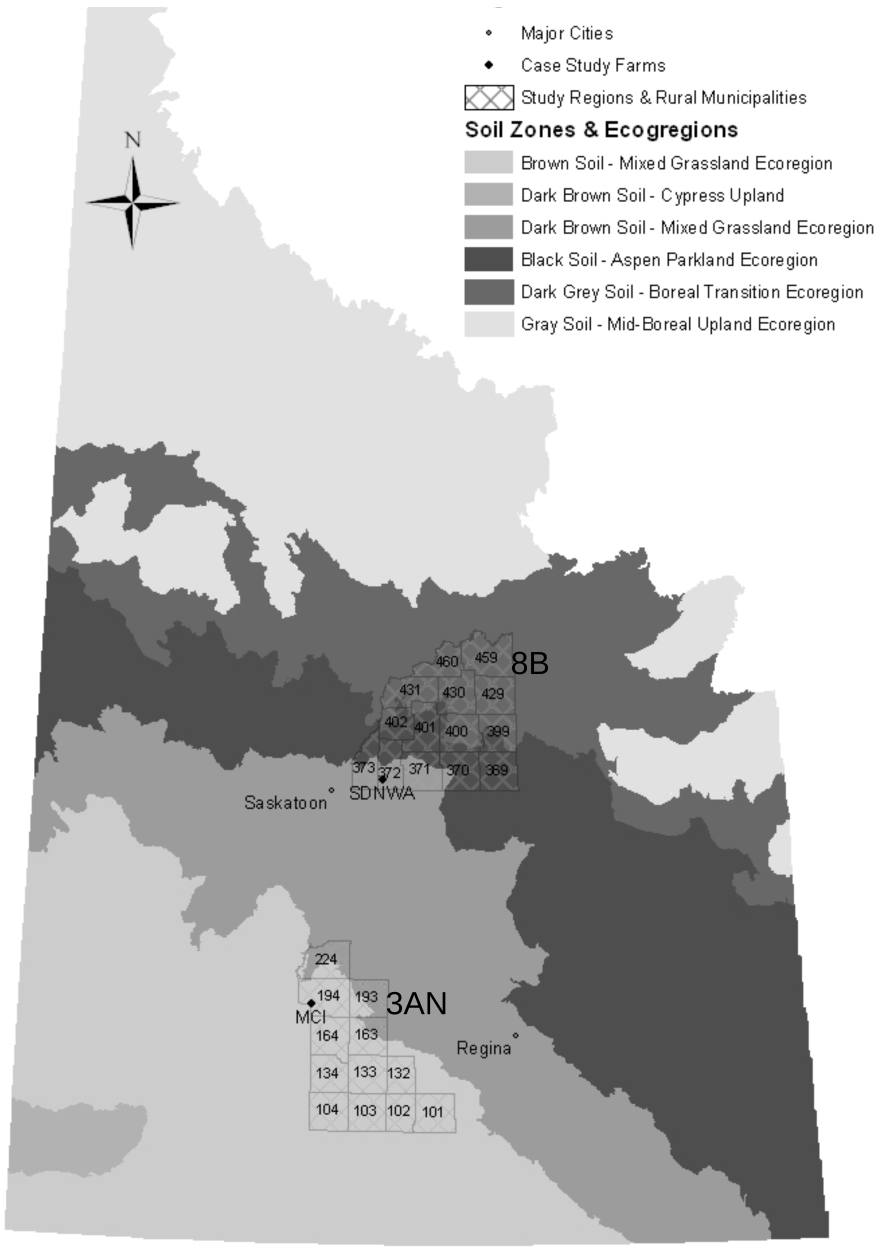

Figure 3.1 The study regions and case study farms in relation to the soil zones and ecoregions of the province of Saskatchewan.

3.3.1.1. Biophysical

The MCI site is located in Brown soil zone and Mixed Grassland ecoregion of south central Saskatchewan (50°39'N, 106°49'W). The site has moderately textured soils on a moderately to steeply sloping, hummocky landscape. The soils of MCI are considered to have severe limitations to agriculture production due to poorly drained depressions, eroded knolls and relatively steep topography (Ayres *et al.* 1985). Prior to cultivation the uplands of the MCI site were dominated by native mid and short-grass species. The wetland and depressional areas are characterized by hydrophytic grasses, sedges, rushes and other herbaceous species, some of the wet margins support willow species (*Salix* spp.) and shrubs (Ayres *et al.* 1985). The climate of the MCI area is characterized by warm summers and cold winters with moderately low precipitation. The temperature ranges, in the extreme, from +42°C in summer to -47°C in winter, July is the warmest month with a mean daily temperature of 19°C while January is the coldest month with a mean daily temperature of -13°C. The average annual precipitation is approximately 372mm with the majority (approximately 70%) of the precipitation falling between May and September (EC 2007).

The SDNWA is located in the transition zone from Dark Brown to the Black soil zone of central Saskatchewan and in the Aspen Parkland ecoregion (52°12'N, 106°5'W). The soils are moderately textured occurring on moderate to steeply sloping hummocky landscape. The soils of SDNWA are also considered to have severe limitations to agriculture production due to poorly drained depressions, eroded knolls and relatively steep topography (Acton and Ellis 1978). Prior to cultivation the dominant upland vegetation at SDNWA was native mid-grasses and some shrubs. The wetlands and depressional areas are characterized by grasses, sedges and hydrophytic herbs and are often associated with woody species including trembling aspen (*Populus tremuloides* Michx.), balsam poplar (*Populus balsamifera*) and willow species (*Salix* spp.) (Hogan and Conly 2002). The climate of the SDNWA area is also characterized by warm summers and cold winters with moderately low precipitation. The extreme temperature ranges from +40°C in summer to -50°C in winter. July is the warmest month with a mean daily temperature of 18°C while January is the coldest month with a mean daily temperature of -17°C. The average annual precipitation is approximately 350mm with the majority (approximately 70%) of the precipitation falling between May and September (EC 2007).

The slightly cooler climate at SDNWA results in a lower evaporative demand than at MCI. Thus, more moisture is available for plant growth at SDNWA than at MCI which has resulted in distinct differences in vegetation composition and soil characteristics including soil organic carbon stores (Table 3.1). The increased available moisture results in increased biomass, including woody species, and subsequent soil organic carbon contributing to greater SOC stores at SDNWA. In addition, SDNWA and CAR 8B are characterized by a greater number of wetlands and riparian treed areas, that occupy a greater proportion of the landscape, than in MCI and CAR 3AN

The wetlands found in the PPR are best described by the Stewart and Kantrud (1971) classification of freshwater prairie wetlands (Table 2.4). This classification divides freshwater wetlands into 5 classes determined by the permanency of water in the basin throughout the growing season. For the purpose of this study wetlands have been fitted into two categories: 1) seasonal wetlands (Stewart and Kantrud (1971) class 1, 2 and 3 wetlands); and 2) permanent wetlands (Stewart and Kantrud (1971) class 4 and 5 wetlands). This distinction was based on how wetlands are currently allocated on the landscape. In general, the wetlands that remain on agricultural landscapes are those that are not suitable for crop production or are too difficult or expensive to drain/cultivate. These are typically semi-permanent, permanent or saline wetlands (NWWG, 1988).

Table 3.1 Estimated current soil organic carbon stores at MCI and SDNWA, Saskatchewan based on results from Bedard-Haughn *et al.* (2006[b]).

Landscape Element	MCI			SDNWA		
	Area (ha)	SOC Density to 30cm[a] (Mg ha^{-1})	SOC Store (Mg)	Area (ha)	SOC Density to 30cm[b] (Mg ha^{-1})	SOC Store (Mg)
Uncultivated Basin[c]	4.5	141.3	637.5	7.8	191.0	1484.1
Uncultivated Riparian[d] (Grass)	5.2	99.9	516.3	8.6	135.0	1159.7
Uncultivated Riparian[d] (Tree)				4.8	195.0	926.9
Cultivated Basin[c]	0.4	76.2	29.9	0.3	103.0	29.9
Cultivated Riparian[d]	7.0	73.2	510.7	3.1	98.9	302.2
Cultivated Upland[e]	47.7	49.9	2380.5	41.8	67.4	2814.5
Total	64.8		4074.9	66.2		6717.3

[a] Based on Bedard-Haughn et al. (2006[b]) data collected at SDNWA in the Dark Brown soil zone. Medium textured soils in the Brown soil zone have about 74% of the SOC in similar soils of the Dark Brown soil zone according to Rostad et al. (1993) and Liang et al. (2005) so estimates for MCI were scaled back accordingly.
[b] Based on Bedard-Haughn et al. (2006[b]) data collected at SDNWA in the Dark Brown soil zone.
[c]Depression elements.
[d]Convergent footslope elements.
[e]Shoulder, backslope & divergent footslope elements.

The nature of wetland allocation in Saskatchewan's PPR allows this study to limit the definition of wetland restoration to the elimination of cultivation from wetland influenced areas on the landscape. In other words, active restoration involving the physical construction of dams or barriers is not considered. In the case of permanent wetlands, the majority of basins still remain intact on the landscape but wetland margins or riparian areas have been encroached upon by cultivation which limits their ability to function. Restoration and enhancement of the function of these permanent wetlands can often be achieved by simply expanding riparian areas surrounding the existing basins to reflect the true influence of wetlands on the landscape. Many of the seasonal wetlands across the landscape have been cultivated and cropped in their entirety, essentially eliminating their presence on the agricultural landscape. The restoration of these seasonal wetlands would require the cessation of cultivation through both their basins and riparian areas.

3.3.1.2. Socio-economic

Both of the study regions are pre-dominantly agricultural regions. Farm socio-economic data was acquired using a mail-out survey conducted in July 2007 (Appendix D). Further details of the survey will be discussed in later sections of this paper. Comparisons between the study regions were conducted in SPSS v.15 using a 2-sample t-test and ANOVA for continuous data and a chi-square test for categorical data with a significance level of $\alpha=0.05$ (Table 3.2).

Table 3.2 Socio-economic characteristics of farms and operators, N signifies sample size.

Characteristic	3AN (N)	8B (N)	All (N)
Mean Age	52.2 (55)	51.9 (157)	52 (212)
Median Education	High School/Tech. Diploma (55)	High School/Tech. Diploma (57)	High School/Tech. Diploma (212)
% Farmers with Off-Farm Income	51 (55)	58 (157)	56 (212)
Mean Years Continuing to Farm	19 (45)	16 (127)	17 (172)
Mean Years Farm in Family	75 (54)	69 (156)	71 (210)
Mean Farm Area	809 (55)	678 (151)	713 (206)
Mean proportion owned (%)	83* (55)	73 (151)	76 (206)

* Significant at $P<0.05$

The only characteristic that is significantly different between regions, based on our survey results, is land tenure. Farmers in 3AN are more likely to own a larger proportion of their land, but from a practical aspect this difference is negligible as the vast majority of land in both regions is owned. The average farmer is 52 years of age, has a high school or technical diploma and plans to continue farming for 17 years. Of farmers planning to retire within the next 10 years, only 21% indicate that someone in the family will take over the farm, 44% indicate that no one in the family will take over, but most notably 34% did not know. Many farmers indicated that they didn't know how long they would continue to farm *because* there was no one to take over. Some farmers said that they would continue farming as long as their health held up or until they died. For many farmers this uncertainty indicates that there is lack of a defined planning horizon which may influence how they make their farm management decisions. There is definitely a sense of frustration among the aging farm population. This uncertainty among a large proportion of the farm population adds to the challenge of designing effective environmental policies.

3.3.2. Farmer Characteristics

As a component of the research a survey was conducted in both study regions to help identify farmer characteristics that may influence the management of wetlands on agricultural fields and participation in the current environmental programs available to farmers (Appendix D). Ethics approval was granted for this survey by the University of Saskatchewan Behavioural Research Ethics Board on June 26, 2007 (Appendix C). A letter of invitation (Figure D1), survey questionnaire (Figure D2) and prize draw form (Figure D3) were delivered to all registered farm mail boxes in CAR 3AN and 8B on July 10, 2007 followed by a reminder post card (Figure D4) three weeks later. To increase the response rate all completed surveys received within 8 weeks were entered into a draw for a prize valued at $200 cdn. A total of 4110 surveys were mailed out, approximately 650 of these were mailed to farmers located outside of our study regions. Although it was assumed that all farmers in the study regions received a survey, the nature of the delivery mode makes it is impossible to estimate how many of the surveys went undelivered. The response rate to the survey was 5.2% in CAR 3AN and 6.5% in CAR 8B, within an overall response rate was 6.1%. The different response rates between regions may be related to the timing of harvest in 2007, CAR 3AN began harvest relatively early (late July) which may have distracted farmers from completing the survey. In addition, since it was impossible to determine the actual number of surveys received by study area farmers the response rate reported above represents a minimum response rate with the actual response rate greater than or equal to this but unknown.

Due to the relatively low response rate of this survey, demographic characteristics were compared to 2006 Statistics Canada Census of Agriculture data to determine if our sample was representative of the population. Average farm size and farmer age were compared for each R.M. in the study regions, no significant difference was found between the census data and our survey data for these variables. This indicates that in terms of demographics, our survey sample was representative of the population within each region. There was a likely bias towards crop producers as the majority of the questions referred to crop production, as a result very few surveys were returned from cattle producers.

The survey data was used to conduct an econometric analysis of the potential influences on wetland management and participation in environmental programs. This analysis was completed using a Logit binary response multiple regression model in EVIEWS v. 5.1.

Understanding the characteristics that influence wetland management and participation in the current programs can help determine if using financial incentives is a valid way to proceed in wetland conservation policy. We identified the maintenance of riparian buffers and plans to drain wetlands in the next 5 years as dependent variables representing wetland management in the econometric analysis. Participation in the Environmental Farm Plan program (EFP) was chosen as a dependent variable to represent a current economic incentive-based environmental program.

The EFP program was chosen because it is available to all farmers in our study regions and it facilitates the flow of financial incentives from partner economic-incentive based programs. The EFP program was developed by the Canadian federal government as part of its' new Agricultural Policy Framework (AAFC 2008). Environmental Farm Plans are voluntary self-assessments to promote awareness of environmental sustainability and environmentally beneficial management practices (BMP). Each province oversees delivery in its jurisdiction. In Saskatchewan EFPs are delivered and reviewed by the Provincial Council of Agricultural Development and Diversification Board, a non-profit agricultural organization that specializes in the delivery of farm programming (PCAB 2008). Farmers who have completed an EFP and who have had it reviewed and accepted are eligible to apply to the Agriculture and Agri-Food Canada's National Farm Stewardship Program and Greencover Canada program which offer cost-shared incentives up to a maximum of $30,000 to implement environmentally beneficial management practices identified in their EFP. An econometric analysis on EFP relevant survey data was conducted to help identify the characteristics that influence participation in environmental management in the presence of economic incentives. The EFP program was considered to be a suitable representative of an economic incentive-based program as 90% of those respondents from our survey who had conducted an EFP indicated that they did so to access funding. This indicates that participation was largely based on financial incentives.

For analysis of the survey responses it was assumed that farmers that maintain riparian areas surrounding wetland basins, including permanent wetlands, exhibit an intention to manage for environmental benefits of healthy wetland ecosystems. Alternatively, farmers that plan to drain wetlands or remove trees and shrubs in the riparian zones and wetland basin do not exhibit a voluntary intention to manage for environmental goods and services. Thus, the Logit models were expected to show that the same characteristics were significant in both wetland management models but with opposite coefficient signs. The EFP model was run to determine if the same characteristics influence participation in environmental management when financial incentives are involved. Each model used the same explanatory variables. Continuous data variables included farmer age, farm size, land tenure (proportion owned) and land productivity. Categorical data variables included the opinion variable that the benefits of wetlands outweigh the disadvantages, education level, and tillage method. Explanatory variables were chosen to represent demographic, regional, opinion and economic (e.g. land productivity) influences. However, the regional and land productivity variables were correlated and had a detrimental impact on our model results. Thus, the models were ran separately with either the regional or productivity variable to determine which provided a better goodness-of-fit. It was found that the productivity variable resulted in a better goodness-of-fit for all three econometric models, therefore the regional variable was discarded for the models presented in our results.

The underlying hypothesis to this econometric analysis was that the economic variable, namely land productivity would have the greatest influence on wetland management in the absence of financial incentives. Since farmers are eligible for compensation for implementing beneficial management practices outlined by their EFP, it was expected that the productivity variable would not be a significant influence in the EFP model. If this hypothesis holds true, the use of economic incentives to encourage participation in a wetland conservation program would be supported.

3.3.3. Developing Incentive-Based Policy

Provided that economic incentives are an effective way to proceed with a wetland conservation policy, it is essential to determine how to effectively meet ecological objectives. Wetland and riparian restoration and (or) maintenance to achieve healthy wetland ecosystem functioning on the landscape is the main objective of the proposed wetland conservation policy. Landscape function is defined as the net effect of all ecosystems on the landscape which includes synergistic effects. The value of individual wetland depends on where they are in the landscape and how closely associated they are with other systems (Leibowitz *et al.* 2000, Mitsh and Gosselink 2000). The policy should also have a mandate of no-net loss of wetlands.

Previous studies have shown that, in general, it is believed that farmers should be compensated for providing public goods (Claassen *et al.* 2001 and Weersink *et al.* 1998). Incentive programs are viewed as being more flexible than regulatory regimes because they allow farmers to weigh the costs vs. the benefits before they choose to participate in the program. In addition, farmers will choose the strategy that yields the most private benefits which inherently selects the most cost-effective farms to adopt the program. However, the efficiency of the program is greatly influenced by the program design and the payment amount.

A wetland conservation program that uses financial incentives seeks to offset the costs associated with restoring and maintaining wetland and riparian areas. The theoretical financial incentive value that would be required for farmers to participate in wetland restoration and maintenance is based on a financial incentive value that offsets the private costs. As discussed previously, the restoration of wetlands in this study is limited to the elimination of cultivation from wetland influenced areas. Thus, for the purpose of this study, the private costs incurred are limited to the opportunity cost associated with foregone crop production. The additional costs that could be incurred as a result of re-seeding perennial vegetation to reduce weedy species or hasten the restoration process can be fully or partially covered by existing government and non-government programs such as the Canada-Saskatchewan Farm Stewardship Program (CSFSP) or the Greencover Canada program and were not considered further in our analysis.

An investigation of the potential for incentives in wetland conservation policy requires a realistic program timeframe. Many past and existing conservation programs such as the U.S. Conservation Reserves Program (CRP) and Canada's Greencover Program used a commitment period of 10 years. To remain consistent with existing conservation programs, our research also proposed a 10 year period for a potential wetland conservation program.

3.3.3.1. Spatial targeting of wetland and riparian restoration

To meet social and environmental objectives it is assumed that some form of targeting will be required. To determine the areas that a policy should target it is important to understand what is required for ecosystem functioning at both the landscape and local or individual scale. At a landscape scale, Mitsch & Gosselink (2000) suggest that 3-7% of temperate regions should be dedicated to wetlands. However, applying the precautionary principle we propose more stringent guidelines for our policy which would mandate that at least 10% of the landscape be composed of wetlands. In this section we look at a number of scenarios for targeting wetland conservation programs that would result in wetlands comprising greater than 10% of the landscape and apply these scenarios to the case study farms. For each scenario it would be required that all existing wetlands be maintained on the landscape to be eligible. The feasibility of each scenario will be discussed in the results within a socio-economic and environmental context, looking at opportunity and restoration costs and the carbon sequestration benefits. The feasibility of using carbon markets in conjunction with conservation program payments will be investigated as policy instruments to offset private costs and encourage adoption of the wetland conservation program.

Two aspects of spatial targeting were considered for a potential wetland conservation program. The first consideration was the class of wetland to be targeted. In this case we looked at the option of targeting all classes of wetlands (seasonal and permanent) to reflect the true wetland influence on the landscape which would require re-establishing seasonal wetlands that have been under cultivation for several decades. Another option was to target only existing permanent wetlands for riparian expansion and maintenance.

The second consideration is the amount of area that should be allocated to riparian vegetation. There is not a general consensus among scientists regarding a standard riparian zone width required for healthy wetland functioning in the PPR. However, a few examples in the literature indicate that a riparian buffer width of 10-30m is usually required for proper functioning depending on the size and class of wetland (Huel 2000, Rickerl *et al.* 2000, Phillips *et al.* 2005). In the present research the three program options considered for riparian width surrounding the wetland basin are as follows:

1) Precision width riparian zone to reflect the true wetland influence on the landscape, as based on air photos, vegetation surveys and soil electrical conductivity.
2) Fixed, 10 meter width riparian zone surrounding the wetland basin
3) Fixed, 20 meter width riparian zone surrounding the wetland basin

In total, six spatial targeting scenarios were investigated for each study site (Table 3.3). Digitized polygons were constructed in ArcGIS 9.1 for cropland, riparian grass, riparian tree and basin elements at each site (van den Bos 2005). The area of the polygons were calculated and summed for each land use under each of the targeting scenarios described (Appendix A, **Error! Reference source not found.**). The potential opportunity costs, carbon sequestration potential and incentive values were based on the calculated set-aside areas for all targeting scenarios.

Table 3.3 Spatial targeting scenarios for the case study farms.

	a. Precision riparian width	b. Fixed riparian width - 10m	c. Fixed riparian width - 20m
1. Target all wetlands (seasonal & permanent)	1. All wetlands a. Precision riparian	1. All wetlands b. Fixed riparian - 10m	1. All wetlands c. Fixed riparian - 20m
2. Target permanent wetlands	2. Permanent wetlands a. Precision riparian	2. Permanent wetlands b. Fixed riparian - 10m	2. Permanent wetlands c. Fixed riparian - 20m

3.3.3.2. Private cost estimation

The opportunity cost of wetland and riparian restoration was estimated based on two alternative indicators: 1) private lease rates and 2) the cost of forgone crop production. The production values for the cultivated riparian elements at both MCI and SDNWA were calculated using: 1) variable production costs for the Brown and Dark Brown soil zones (SAF 2006[c] and SAF[d]); 2) the 10 year minimum, maximum and average yield for Canadian Western Red Spring wheat (CWRS) for the respective municipalities (SAF 2007[a]) and 3) the 10 year minimum, maximum and average Canadian Wheat Board on-farm price for CWRS wheat (SAF 2006[b]) (Table 3.4).

Table 3.4 Estimated opportunity cost of retiring wetland-influenced areas (CAD).

CAR	Soil Zone	Rental Rates[a]			Production Value[b]		
		Minimum ($ ha^{-1})	Maximum ($ ha^{-1})	Mean ($ ha^{-1})	Minimum ($ ha^{-1})	Maximum ($ ha^{-1})	Mean ($ ha^{-1})
3AN	Brown	49.4	86.45	61.75	-34.54	162.1	73.87
8B	Dark Brown	24.7	118.56	76.20	-120.04	218.38	117.23

[a] SAF 2006[a]

[b] Returns over variable expenses for CWRS wheat using: average yield data 1997-2006 SAF (2007), represents the cultivated riparian and basin elements in the field which are estimated to be 1.2 times greater than the mean yields in their respective regions (ACAAF 2007 unpublished data); Average price data 1997-2006 SAF (2006[b]); and 2007 estimated expenses SAF (2006[c]) & SAF(2006[d]).

Canadian Western Red Spring wheat was used in this study as it is the most commonly grown crop in Saskatchewan, accounting for an average of 30% of the total seeded area over the last 10 years (SAF 2007[b]). Due to the prevalence of CWRS wheat production in Saskatchewan it is often the focus of crop production studies in the literature. As well, accurate data on CWRS yield and price are readily available for analysis.

In the study area, previous research has shown that riparian areas that were converted to cropland are often the most productive areas on the field due to greater moisture availability, organic matter, N mineralization and favorable textural composition (Pennock *et al.* 1994, Jowkin and Schoenau 1998, Si and Farrell 2004). Pennock *et al.* (2001) found that canola yields in the black soil zone were 1.47 times greater in the depressional elements than the field mean. Jowkin and Schoenau (1998) found that spring wheat yields in footslope elements in the brown soil zone were 1.15 -1.29 times greater than the field mean. Based on this research, in the current analysis yields for the cultivated riparian landform elements were estimated to be 1.2 times greater than the 10 year average yields reported for the respective rural municipalities based on ACAAF (2007) unpublished data.

While it is recognized that there is a broad range of rental rates and production values, the production value of land was used in this study because it is often higher than the lease rates for a given region, which provides a more conservative benefit: cost estimate. As well, when land is being leased it is likely that the entire field would be leased and the lease rates are reflective of the entire parcel of land. Thus, the lease rate is not a true reflection of the value of the more productive cultivated riparian areas. The average returns over variable expenses for CWRS wheat in cultivated riparian elements in the Brown soil zone is estimated to be $73.87 per ha and in the dark brown soil zone it is $117.23 per ha (Table 3.4).

The minimum, maximum and average net revenues for CWRS wheat in each region were multiplied by the total area that would be restored to riparian vegetation under the different land allocation scenarios to give the total annual opportunity cost (Table B2). To correspond to the proposed program commitment period, the present value opportunity cost for the 10 year period was calculated based on a 5% discount rate.

3.3.3.3. Financial incentives

Two alternative incentive methods investigated in this research are a carbon-based payment and a conservation program payment. A carbon-based payment may be obtained through a free-market carbon trading system, such as that which is represented in the Chicago Climate Exchange (CCX). A conservation program payment would be a publicly funded program that provides an area-based payment based on the total area dedicated to wetland and riparian areas, while carbon payments are based on the total amount of carbon sequestered per unit area as a result of implementing the beneficial management practices.

The SOC sequestration potential of a given area is dependent on two overarching controls: 1) the initial SOC content prior to carbon sequestration practices and 2) the rate of C input with specific management practices under the prevailing environmental conditions (Janzen 1998, VandenBygaart *et al.* 2003 and Pennock 2005). On the case study farms two management practices that will lead to SOC sequestration were considered: zero-till and riparian vegetation restoration. In this study the SOC sequestration rates and the total amount of carbon that can be stored over a 10 year period were determined for the two case study farms for the cropped elements under zero-till and the riparian and basin landform elements with restored permanent vegetation. The total amount of carbon that can be sequestered was converted to atmospheric CO_2 equivalents which is the measurement used for carbon contracts on the CCX.

There is a general consensus that SOC sequestration by zero-till can be sustained for 20-50 years before a steady state is reached (Dumanski *et al.* 1998, Boehm *et al.* 2004, Desjardins *et al.* 2005). Both of the case study farms have employed zero-till for approximately 10 years so it was assumed that the cropped elements will continue to sequester carbon at a stable rate for at least another 10 years if no-till management is maintained. Previous research has indicated that annual carbon sequestration rates of cropland under zero-till ranges from 0.08 to 0.20 Mg C ha^{-1} yr^{-1} in the Brown soil zone and 0.14 to 0.37 Mg C ha^{-1} yr^{-1} in the Dark Brown soil zone (Boehm *et al.* 2004, Liang *et al.* 2005, McConkey *et al.* 2000, Smith *et al.* 2001, Vandenbygaart *et al.* 2003). The case study farms are considered to represent average farms in their respective soil zones so we would expect they would sequester carbon at their regional mean rates (Table 3.5).

Table 3.5 Annual carbon sequestration co-efficients for cropped elements under zero till; and wetland basin and riparian elements with restored permanent vegetation.

Region	Basin[ab] (Mg C ha^{-1} yr^{-1})	Riparian[ac] (Mg C ha^{-1} yr^{-1})	Cropland[d] (Mg C ha^{-1} yr^{-1})
Brown Soil Zone - MCI	0.80	0.77	0.12
Dark Brown Soil Zone - SDNWA	1.07	1.03	0.23

[a] Average annual SOC increase based on a 1% increase each year for 20 years (Pennock and Elliot 2007).
[b] Depression elements and
[c] Convergent footslope elements (Pennock *et al.* 1994).
[d] Regional mean carbon sequestration rate for cropland under zero-till (Boehm *et al.* 2004, Liang *et al.* 2005, McConkey *et al.* 2000, Smith *et al*. 2001, Vandenbygaart *et al*. 2003)

Few studies in the literature investigated the potential of pothole wetlands and riparian areas to sequester carbon when permanent vegetation is restored. Bridgham *et al.* (2006) estimated that carbon could be sequestered in restored prairie wetland soils at rates ranging from 0.17-1.85 Mg ha^{-1} yr^{-1} but these estimates were presented with a very high level of uncertainty. Euliss *et al.* (2006) found that restored wetland soils can sequester up to 3.05 Mg C ha^{-1} yr^{-1}. For the purposes of this study the restored wetland and riparian carbon sequestration co-efficients were based on the estimates presented by Pennock and Elliot (2007) for the SDNWA. They found that when cropland was restored to permanent cover SOC could be sequestered at an average rate of 1% per year over a 20 year period. Based on the initial SOC estimates (Table 3.1), the SOC sequestration rates for wetland and basin areas were calculated at a 1% annual gain (Table 3.5). It is assumed that existing riparian and basin areas are currently at a steady state so no additional C is sequestered by maintaining these areas

3.4. Results

3.4.1. Farmer Characteristics

The decision to participate in environmentally beneficial management practices is not based on economic factors alone. Demographic factors as well as opinions and attitudes can affect the adoption of a wetland conservation practices (Gelso *et al.* 2008). The results of the wetland management and environmental farm plan Logit models are presented in Table 3.6. The riparian maintenance model suggests that with increasing land productivity, farmers are less likely to maintain riparian zones surrounding wetland basins. As was expected, in the wetland drainage model, the coefficient for land productivity is also significant ($P<0.05$) but positive. In other words, those with more productive land are more likely to drain wetlands or push bush. This is not surprising given that productivity is directly related to profitability (i.e. opportunity cost).

Farmers' opinions regarding wetlands also influence their willingness to maintain riparian areas (Table 3.6). Farmers who agreed that the benefits of wetlands outweigh the disadvantages were twice as likely to maintain riparian areas around at least their permanent wetlands (the same is not true for seasonal wetlands). However, the co-efficient for this opinion variable was also significant ($P<0.05$) and positive in the wetland drainage model which is contrary to what we expected. This indicates that farmers who plan to drain wetlands or remove bush from their land also think that the benefits of wetlands outweigh disadvantages. Perhaps when farmers responded to this opinion question they recognized the social benefits of wetlands but despite this they consider the private cost of maintaining wetlands and natural areas too high. This survey result may also be influenced by the fact that the survey was conducted in a flood year for CAR 8B, therefore their responses to draining may have been a result of their frustration. It is possible that if the study had been conducted in a dry year the results may have differed but there is no way of supporting this postulate with the existing data.

Tillage method was also found to be significant ($P<0.05$) in the wetland drainage model. Those who practice conservation tillage or zero-till, both considered to be environmental management practices by reducing erosion and improving soil health, were less likely to drain wetlands or push bush.

In contrast to wetland management practices, participation in the EFP program is significantly influenced by demographic variables such as age and farm area ($P<0.01$). Alternatively, the wetland opinion (benefits>disadvantages) and land productivity variables had no significant predictive value for farmers who conducted EFPs while these variables were highly significant in predicting farmers' wetland management practices. This is an important finding as it indicates that financial incentives are effective in encouraging farmers to participate in environmental management. The effect of opinions and land productivity variables in predicting environmentally beneficial management practices diminished because compensation is provided.

Table 3.6 Influences on wetland management and participation in the Environmental Farm Plan Program using a Logit binary response model.

Explanatory Variable	Maintain Riparian Around Permanent Wetlands			Plan to Drain in Next 5 Years			Conducted or Planning to Conduct EFP		
	Est. Co-efficient	Std. Error[a]	Z-Statistic	Est. Co-efficient	Std. Error[a]	Z-Statistic	Est. Co-efficient	Std. Error[a]	Z-Statistic
Constant	0.34	1.61	0.21	-3.95**	1.22	-3.24	1.05	1.85	0.57
Age	0.02	0.01	1.11	-0.01	0.01	-0.55	-0.04**	0.02	-2.51
Education	0.10	0.17	0.56	0.20	0.12	1.61	0.19	0.20	0.94
Total Farm Area	0.00	0.00	1.30	0.00	0.00	0.98	0.01**	0.00	2.74
Proportion Owned	0.00	0.01	0.25	-0.00	0.00	-0.48	-0.01	0.01	-1.63
Land Productivity	-0.07*	0.04	-1.99	0.06*	0.03	2.25	-0.01	0.04	-0.15
Tillage	0.26	0.22	1.18	-0.45*	0.19	-2.37	0.62*	0.27	2.32
Benefits of Wetlands > Disadvantages (-1=Disagree; 0=Neutral; 1=Agree)	0.68**	0.25	2.72	0.48*	0.20	2.41	0.43	0.27	1.47
No. of observations		182			170			185	
Log likelihood		-11571			-70.39			-89.56	
Likelihood ratio χ^2 (df)		17.71**(7)			37.36**(7)			58.21**(7)	
McFadden $\overline{R}^2$		0.07			0.21			0.25	

[a] Huber/White robust standard error
**indicates significance level where *P*<0.01, * indicates significance level where *P*<0.05

The EFP model shows that respondents with larger farms were more likely to conduct an EFP. Larger farms tend to be run more like a traditional business model with the farm managers dedicating more time to taking care of the business aspects of the farm operation such as finances and planning and less time doing labour (Claassen *et al*. 2001). Thus, it is not surprising that they are more likely to have the taken the time required to conduct an EFP. This is further supported by the fact that of those survey respondents who had not conducted a farm plan, 42% indicated that they did not have time.

The EFP model suggests that older farmers are less likely to conduct an EFP. This may be due to the complexity of these programs. For example, 30% of farmers indicated that they had not conducted an EFP because there was too much paper work. Also, a relatively large percentage (30%) of farmers had not conducted an EFP because they had never heard of the program. Many aging farmers have limited knowledge of computers and internet which has arguably become the most often used mode of communication. Perhaps information about these programs is not reaching the entire target audience because they do not have access to computer related media; further research is needed to investigate this postulate.

The EFP model also indicates that farms that already practice some form of conservation tillage are more likely to conduct an EFP. This highlights that those who have already exhibited an intention to manage for the environment are more likely to participate in a program with an environmental focus.

3.4.2. Effectiveness of Incentive-Based Policy Tools

Each of the spatial targeting scenarios was evaluated in terms of carbon sequestration potential and mean opportunity cost of production over a 10 year period based on the total area restored to wetland vegetation. Based on the GIS analysis the area dedicated to restored wetland vegetation ranges from 0.1 to 5.2 hectares at MCI and 0.0 to 7.1 hectares at SDNWA (Appendix B). With each case study site occupying approximately 1 quarter section of land (~65 ha), less than 10% of the total field would be dedicated to restored riparian vegetation for any of the targeting scenarios. Yet, restored and existing wetland influenced areas combined can occupy up to 23% and 43% of the landscape at MCI and SDNWA, respectively.

The estimated total carbon that can be sequestered over a 10 year program period ranges from 66 to 100 Mg C (242-365 t CO_2) at MCI and from 104 to 161 Mg C (380-589 t CO_2) at SDNWA (Table 3.7). It is important to note that the predicted increases in soil carbon above initial carbon stores were relatively small. This warrants some discussion. First, despite the land being cultivated there were still relatively large stores of SOC prior to management changes which sequester carbon thereby making small changes in carbon difficult to detect. Furthermore, this study only looks at a 10 year horizon which is insufficient time for the soil to reach its full carbon carrying capacity.

Table 3.7 Total soil organic carbon sequestered and atmospheric CO_2 equivalents over 10 years under different management scenarios.

Management Scenario	MCI			SDNWA		
	Total SOC (Mg)	CO_2 Equivalent (t CO_2)	Increase in Carbon from Initial (%)	Total SOC (Mg)	CO_2 Equivalent (t CO_2)	Increase in Carbon from Initial (%)
No Change	66.1	242.0	1.6	103.8	379.9	1.5
All wetland Precision riparian (1a)	80.6	294.8	2.0	130.7	478.3	1.9
All wetlands Riparian-10m (1b)	77.0	281.7	1.9	121.6	444.9	1.8
All wetlands Riparian- 20m (1c)	99.7	365.0	2.4	160.9	588.7	2.4
Permanent wetlands Precision riparian (2a)	71.2	260.4	1.7	103.8	380.0	1.5
Permanent wetlands Riparian - 10m (2b)	67.0	245.1	1.6	103.8	379.9	1.5
Permanent wetlands Riparian - 20m (2c)	77.0	281.7	1.9	106.2	388.8	1.6

It is also important to put the carbon sequestration potential of a single agricultural field into a social perspective. It is estimated that Canada emits 550.9 million t CO_2 from fuel combustion annually which is 17.24 t CO_2 per capita (OECD 2006). This indicates that, at the MCI study site, the C sequestered by the different scenarios can offset fuel combustion emissions of 0.4-0.6 individuals per year and at SDNWA 0.6-1.0 individuals per year. So in terms of carbon sequestration benefits there is really no practical difference between any of the scenarios.

The total carbon that is predicted to be sequestered by the various landscape elements over a 10 year period is shown in Figure 3.2b. Over 60% of carbon sequestered under all management scenarios would be due to the influence of zero-till on the cropped areas. However, the wetland influenced areas have a disproportionate effect on carbon storage relative to the total area that they occupy. Although restored wetland areas occupy a relatively small proportion on the landscape, they still make important contributions to the overall field carbon budget. For example under scenario 1C (all wetlands targeted with a minimum 20m riparian width) the restored wetland areas occupy only 10% of the landscape but account for 46% of the carbon sequestered. Figure 3.2 also highlights that the management scenarios with the greatest carbon benefits are also associated with the greatest costs. This comes as no surprise as the scenarios that have the greatest carbon benefits require that a greater amount of land be removed from crop production which leads to increased opportunity cost.

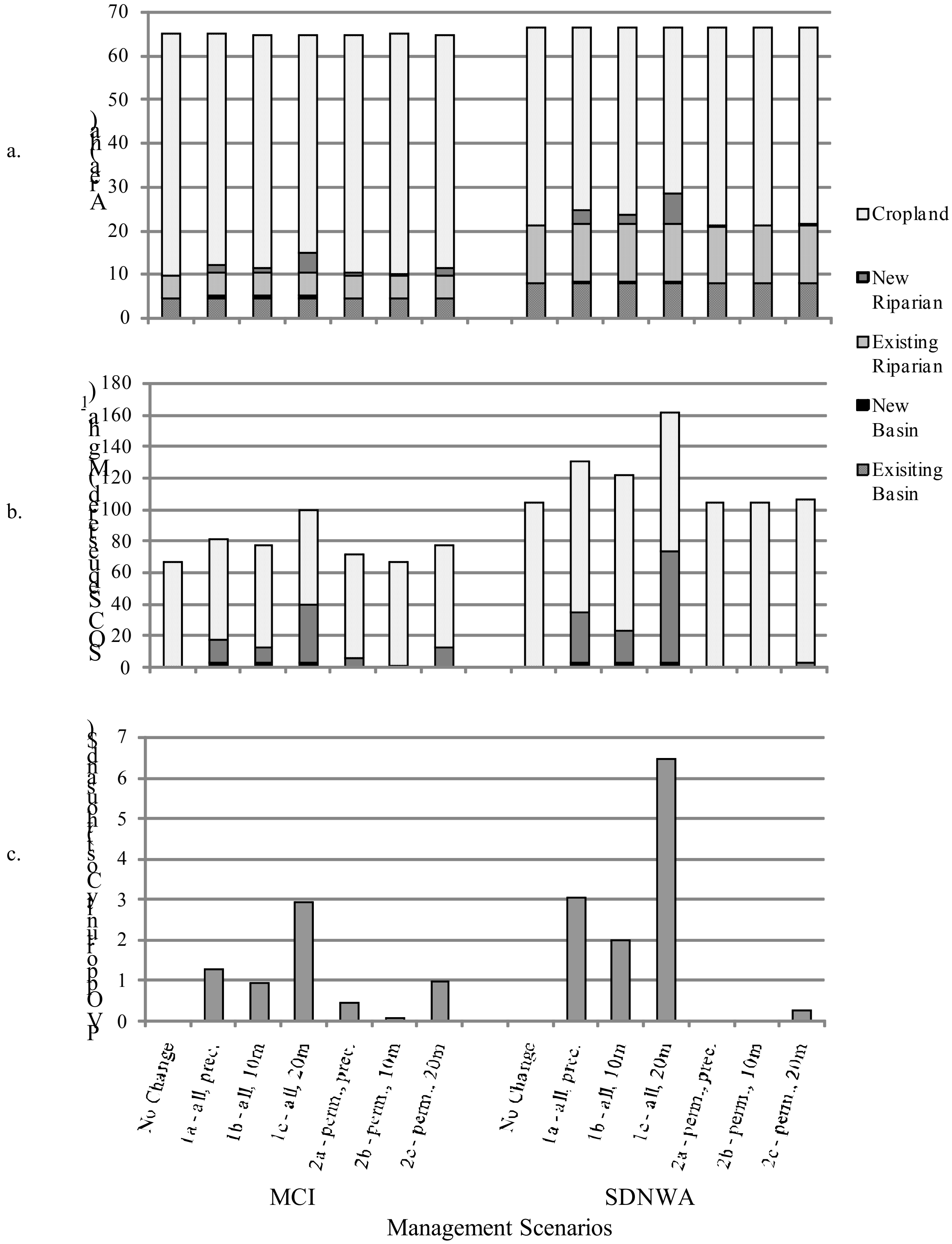

Figure 3.2 Land use allocation (a), total soil organic carbon sequestered (b) and present value opportunity cost (discount rate *(r)* =5%) (c) over a 10 year period for different management scenarios at MCI & SDNWA.

Considering the alternative targeting scenarios, the precision riparian width would be optimal in terms of environmental benefits because precision riparian width reflects the true extent of wetlands. Restoring wetlands to their true extent on the landscape would have a greater probability of providing healthy, functioning wetland ecosystems. The administration costs of implementing a program that requires the provision of precision riparian zones on a landscape would likely be significant due to the requirement for extensive expertise and field data (i.e. soil electrical conductivity, vegetation surveys, digital elevation models and multiple aerial images) to delineate these areas accurately. In contrast, limited expertise and field data are necessary to delineate a fixed riparian width so transaction costs are greatly reduced and fixed riparian width is more user friendly, thus more likely to be adopted.

For the two case study farms, there is no obvious environmental advantage to develop a policy that targets only permanent wetlands with a 10m riparian width. At the other extreme, providing a 20-m riparian buffer around all wetlands provides maximum environmental benefits but is highly costly since the riparian area often extends into the surrounding uplands and as such has a greater impact on cropland management (Figure 3.2 and Appendix B).

At MCI the mean opportunity costs and carbon benefits for the scenario that targets permanent wetlands with a 20 m riparian width and the scenario that targets all wetlands with a 10 m width are roughly equivalent. However, at SDNWA the opportunity cost and carbon benefits of providing a 20m riparian zone around existing wetlands is considerably less than providing a 10m riparian zone around all wetlands (Figure 3.2). This is because SDNWA already has 20m riparian zones for the majority of permanent wetlands so there are essentially no additional costs to maintaining these areas but there are also no carbon sequestration benefits. The difference between the two sites could be due to different management goals. The SDNWA is managed as a wildlife area so riparian areas have been provided to maximize wildlife habitat. The only potential for improving carbon sequestration in riparian areas at SDNWA is for seasonal wetlands (mostly Stewart and Kantrud (1971) class 1 and 2) to be fully restored. Alternatively, MCI is privately owned and managed for crop production so the goal has been profit maximization not environmental benefits. Alternatively, the difference between the two farms could be a regional difference in that farmers in the aspen parkland are forced to provide wider riparian zones due to woody vegetation growth that deters cultivation in these areas.

An effective compensation amount for farmers to adopt a wetland conservation program was considered using a benefit/cost ratio. A ratio greater than 1 indicates that the program payments exceed the mean opportunity costs and farmers should accept the program. The results of the benefit-cost analysis and the proposed program payment amount can be seen in Table 3.8.

Table 3.8 Estimated payments (CAD) required to offset opportunity cost from a wetland conservation program alone and interplaying with the carbon market.

Study Region	Conservation Program Payment Alone		Conservation Program Payment in Conjunction with Carbon Market[b]		
	$ ha^{-1} yr^{-1}	Total Program Payment[a] $ yr^{-1}	$ ha^{-1} yr^{-1}	Total Program Payment[a] $ yr^{-1}	Reduction[c] (%)
3AN	75.00	4,008,750	60.90	3,255,105	18
8B	95.00	7,876,488	76.15	6,313,626	20

[a] The total payment that would be expected to come from the publicly funded program if 10% of the total cropland area in 3AN & 8B was dedicated to wetland and riparian areas.
[b]Estimated carbon contract value at $5.00 CAD t^{-1} CO_2 yr^{-1} based on CCX trends.
[c] Reduction in the publicly funded portion of the conservation program as a result of interplay with the private carbon market.

Carbon contracts on the CCX ranged from \$1.00 to \$5.00 CAD t^{-1} CO_2 yr^{-1} in 2007 and early 2008 which is considerably less than what is needed to cover the mean opportunity cost of production. Likewise, the publicly funded conservation program payments that would be required to offset private opportunity costs are quite high on their own. However, if the two incentives are employed simultaneously, the carbon market can help to reduce the total conservation program payment amount. Based on market trends it is not unreasonable to think that sequestered carbon can be traded for \$5.00 CAD t^{-1} CO_2, by factoring this into a wetland conservation program, payments can be reduced by up to 20% (Table 3.8).

3.5. Discussion

The decision to participate in an environmental program is influenced by a combination of monetary incentives as well as personal beliefs and attitudes. The results of our survey indicate that a majority of the respondents are interested in the environment but the opinions and behaviours of farmers may be in contrast if the private costs are too high. For example, even though many farmers believe that wetlands provide important social benefits they are unwilling to provide them on their fields. It was also found that farmers with more productive land are less likely to manage for wetland conservation. Ultimately, the decision to provide wetlands on the landscape comes down to economic factors. Farm incomes are volatile, forcing many farmers to manage based on economics alone. Providing financial incentives allows farmers to choose to manage for environmental goods and services while maintaining farm income. Our results also highlight the importance of the financial incentive value; the opportunity cost to farmers varies with land productivity so perhaps a conservation program payment should also vary accordingly.

The costs and benefits of the different targeting scenarios for a wetland restoration program are based on the total area restored to riparian vegetation so it should come as no surprise that the programs that yield the greatest carbon benefits also represent the greatest opportunity cost. However, this does not take into account the transaction costs of the different targeting strategies.

It is apparent that spatial targeting scenarios involving precision riparian widths optimize environmental benefits but represent large transaction costs in terms of technical expertise and inconvenience to farmers, as reported by Dosskey *et al.* (2005). Alternatively, implementing a scenario that targets only permanent wetlands with a 10 m riparian zone represents a least cost method but there are also minimal environmental benefits. The scenario that targets all wetlands with a 20 m riparian width yields the most carbon sequestration benefits but it is also represents the greatest opportunity cost and is probably the least likely to be adopted by farmers as a result of inconvenience.

The ecological benefits of restoring seasonal wetlands on the landscape must be included in the evaluation of wetland conservation policy. There is a potential for more carbon to be sequestered and the biological diversity gained from restoring these areas would be greater than simply expanding existing riparian areas. However, unless the entire field is restored to permanent vegetation there is a very low likelihood that farmers would adopt a policy mandating seasonal wetlands to be restored on the landscape due to greater inconvenience costs. Gelso *et al.* (2008) found that greater wetland dispersion across the landscape represents larger inconvenience costs; thus, farmers are unlikely to support programs that require a high level of wetland dispersion across the landscape. By simply examining the delineated images in Appendix A, the inconvenience to avoid seasonal wetland areas would be immense for producers, particularly in the Aspen Parkland.

A wetland conservation program that spatially targets existing wetlands and requires at least a 20m riparian zone would be relatively inexpensive to implement and would be appealing to farmers. Although it is unlikely that an efficient wetland policy can be developed that satisfies all environmental and economic criteria but based on the analysis here, this policy does represent a *pareto improvement* (i.e. the winners win more than the losers lose).

It may seem like environmental benefits are sacrificed by developing a wetland policy that is more suited to agricultural systems. However, one must consider that the benefits gained on a landscape scale are far greater if more farmers participate. In addition, concerns have been raised as to the effect of climate change on seasonal wetlands (Johnson *et al.* 2005). Climate models predict a warmer and drier climate in much of the PPR. Many seasonal wetlands are predicted to dry up entirely, diminishing their ability to provide environmental benefits. This further supports targeting permanent wetlands for conservation efforts to achieve long-term benefits.

Although on its own carbon sequestration on agricultural landscapes makes very modest contributions to climate change mitigation, effective mitigation strategies are based on many modest reduction by various means that are economically efficient (Hutchinson *et al.* 2007). The wetland management strategies imposed on each of these study sites will have a negligible regional, let alone global, effect on their own. Furthermore, to enrol in a carbon market such as the CCX the minimum project size is 10,000 t CO_2 annually. Thus, no individual farmer will have the capabilities to trade under the CCX alone but must work with a carbon, such as existing farmer organizations, governments or environmental groups like the Soil Conservation Council of Saskatchewan (SCCS). For a carbon aggregator to be successful it is even more important to develop a policy that is easily implemented and will be widely adopted.

Although this study only looks at a 10 year time period it is important to consider long term implications as well. Even when zero-till is employed, a new steady state will likely be reached on cropped elements within 20 years and this new equilibrium will occur at a SOC level below the maximum potential for that particular field (Boehm *et al.* 2004, Desjardins *et al.* 2005, Dumanski *et al.* 1998). Alternatively, the wetland influenced areas will continue to sequester carbon for several decades and, if left undisturbed, should eventually reach the maximum SOC potential for that particular soil. This study also does not investigate the potential of carbon sequestration in above-ground biomass. Slobodian *et al.* (2002) found that the greatest carbon gains in wetland and riparian areas were actually in the biomass, particularly when woody species were present.

The annual program payments required to offset the opportunity cost of foregone crop production range from $75 per hectare in the Brown soil zone to $95 per hectare in the Dark Brown soil zone. However, if a wetland policy utilizes the carbon market publicly funded program payments can be reduced by 20%.

There are two ways to accomplish co-benefits from the carbon market and a wetland conservation program, easing the strain on the public purse. One option is for farmers to participate in a carbon market independent of the conservation program, the second option is for the conservation program to act as the aggregator and sell carbon on the market on the farmers' behalf (Feng and Kling 2005). The discussion of which option is optimal is beyond the scope of this study.

3.6. Conclusions

This study examined the use of financial incentive-based policy to conserve wetlands on a prairie agricultural landscape by compensating farmers for foregone crop production in wetland and riparian areas. A policy that targets the existing wetlands on the landscape for enhancement (riparian zones must be at least 20 m wide) and maintenance provides moderate social benefits and private costs which can be offset by program payments. Utilizing an existing carbon market in conjunction with a conservation program payment provides environmental co-benefits and can help reduce the publicly funded program payments by 20%.

A note of caution must be exercised when using incentives. It is possible that farmers have been targeted with providing public goods so many times that their willingness to contribute voluntarily is diminishing (Frey and Oberholzer-Gee 1997, Reeson and Tisdell 2006). Sometimes it is necessary to understand what level of environmental benefits farmers can reasonably be expected to provide to society without compensation. It may be useful to carry out a valuation study asking farmers about their willingness to accept value for providing wetlands on their fields. Differences between actual WTA and mean opportunity cost of production may capture farmer’s inherent value in wetlands. This difference should be factored into the program payment amount. It would also be useful to investigate society’s environmental rights within a legislative framework to determine if regulation of wetland management on agricultural landscapes is justified. Of course, such research would also have to address the cost of verifying compliance and enforcement.

4.0 SYNTHESIS, CONCLUSIONS & FUTURE RESEARCH

In this study, land use allocation and management of wetlands in the PPR were investigated. The empirical analysis conducted in Chapter 3 investigated factors that may influence how farmers manage wetlands in the PPR. Factors that may influence participation in an incentive based program such as the Environmental Farm Plan were also investigated. Land productivity was found to be the most important factor in predicting voluntary farmer participation in wetland conservation practices while opinions were also significant. However, participation in the Environmental Farm Plan program is influenced by demographic factors such as age and farm size while opinions were not significant. This indicates that financial incentives may encourage farmers to participate in wetland conservation practices that otherwise would not. Older farmers may be less likely to participate in environmental-based programs because they may be more resistant to change and to government intervention. As well, older farmers may be less inclined to use new technologies that are required to apply and implement environmental programs. Larger farms may be more likely to conduct an EFP because they dedicate more time to business management, thus enabling them to enrol in government-funded programs (Lambert *et al.* 2006). While these are believed to be reasonable explanations for the models provided, further research is needed to verify these explanations.

The survey results in Chapter 3 indicate that 90% of survey respondents participated in the Environmental Farm Plan Program to access funding showing that incentives are largely responsible for participation in the EFP. Thus, the EFP program was used as an example of an economic incentive program in our econometric analysis although in reality it facilitates the flow of incentives while other programs actually provide the funding to farmers. It is also important to note that although the EFP was used an example of an environmental-based incentive program, there is no evidence that the same variables would be significant predictors of a wetland conservation program. Thus, future farm survey research may be needed on a hypothetical wetland conservation program to determine if the same results hold true. It should also be noted that the wetland management and environmental farm plan econometric models had relatively poor goodness of fit. Therefore, it is highly recommended that further research be conducted to validate these findings.

The research in Chapter 3 also investigated the carbon sequestration potential and private costs for different spatial targeting scenarios to determine the strategy that yielded the highest level of carbon benefits relative to costs. At both study sites, a policy that targets permanent and existing wetlands with a minimum riparian 20m buffer would yield the greatest carbon sequestration benefits relative to costs and would likely be adopted by farmers.

Wetland areas have the potential to represent a net carbon sink on the landscape. However, wetland influenced areas often represent the most productive areas on the landscape as well. Thus, there are likely more cost-effective ways to sequester carbon, from a producer perspective, such as converting from conventional tillage to zero-till or converting entire agricultural fields to permanent cover. For this reason, a wetland conservation program should not focus on carbon sequestration as the primary objective. However, a well defined wetland conservation program that requires restoration and maintenance of riparian areas may result in carbon sequestration as a co-benefit. Thus, the carbon that is sequestered as a co-benefit to wetland conservation can be traded on the carbon market to reduce the wetland conservation program cost. The research presented in this study indicates that the publicly funded portion of wetland conservation program payments can be reduced by up to 20% when there is interplay with private carbon markets.

One aspect of public wetland conservation program and carbon market interaction that was not discussed was the transaction costs associated with this interaction. If the wetland conservation program acts as the carbon aggregator the transaction costs are incurred by the governing body (i.e. taxpayers). Alternatively, if farmers are free to trade their own carbon the transaction costs are incurred privately. Furthermore, there is currently no existing carbon aggregator that recognizes carbon sequestered in restored wetland and riparian areas specifically. Therefore, perhaps it is the responsibility of the government to act as the carbon aggregator through a proposed wetland conservation program. More research is needed into the role of carbon aggregators for carbon sequestered in restored wetlands and riparian areas and the potential for wetland restoration practices to be recognized by carbon markets.

An effective wetland conservation policy in the PPR will likely require a range of policy tools to meet environmental objectives. The empirical analysis of this study focused primarily on economic incentives. Rather than strict regulation of wetland management, economic incentives are viewed as being more equitable and effective in ensuring the protection of wetland benefits for society (Lant 1994). In an agricultural context incentive-based conservation programs may be a suitable replacement for programs that provide subsidies based on crop acreage and yield. As a result of shifting the program subsidies away from crop production to production of environmental goods the public is subsidizing a public good, rather than just subsidizing farm income with no public return (Lant *et al.* 2005). This solution could meet the *pareto improvement* criterion; namely, those who benefit from wetland preservation would compensate those incurring costs to maintain public benefits. In addition, it is important for subsidy programs to include the maintenance of existing wetlands as these are the most valuable systems because they are already functioning and providing a high level of ecological goods and services. It can take restored wetlands up to 50 years to achieve a level of functioning comparable to native wetlands (Gutrich and Hitzhusen 2004, Lovell and Sullivan 2006).

It is of utmost importance to determine an effective compensation amount to ensure that the program is readily adopted by farmers. A reasonable compensation amount in this study was assumed to be the opportunity cost of production, that is, the income that farmers would forego to provide wetland and riparian areas. However, this compensation amount ignores two important cost considerations; these costs include nuisance or inconvenience costs and transaction costs.

Inconvenience costs refer to the inconvenience of manoeuvring around obstacles in the field, such as wetlands, with farm equipment. As farm equipment continues to grow in size and power, inconvenience costs of avoiding isolated wetlands increase (Huel 2000). In addition, many prairie farmers have adopted GPS technology to operate their field equipment. With the use of GPS units the operator only has to manually steer when there are obstacles to manoeuvre around such as fence-lines and wetlands. Thus, with increasing numbers and dispersal of wetlands on the field inconvenience costs can be expected to increase greatly (Gelso *et al.* 2008). Future research into the value of nuisance costs can help to refine the compensation amount as well as give policy makers and society a more realistic value of the costs associated with wetland and riparian conservation in agricultural landscapes.

The second cost that was largely ignored in this study was transaction costs imposed during the implementation of the wetland conservation program. Transaction costs are incurred by both the individual participating in the program and the governing body. Transaction costs incurred by private participants include the application process and implementation of the program measures. The cost of application is often over-looked and many government programs fail to recognize that the amount of paper work involved in the application process is prohibitive. In fact, the application process and the volume of documentation required is one of the most common complaints with current government subsidy programs such as the Canadian Agriculture Income Stabilization Program and Environmental Farm Plans in conjunction with the National Farm Stewardship Program. For example, in our survey 30% of respondents that had not completed an EFP claimed that there was too much paper work and 42% said that they didn't have enough time. Minimizing the amount of paper work required to apply for conservation programs and providing technical assistance to implementation can reduce these private transaction costs. Future research is needed to clarify the extent of private transaction costs and their influence on conservation program adoption.

The public transaction costs associated with environmental incentive programs such as those examined in this research include program development and implementation, compliance verification and enforcement. However, these costs would be associated with any government conservation program whether it used regulation, cross-compliance or financial incentives.

Ideally, enforcement costs would be lower for economic incentive programs than for regulatory programs as participation is voluntary and farmers are compensated to comply, but this should not be taken for granted. In chapter 3 it was noted that those targeting scenarios requiring precision conservation techniques would be associated with greater transaction costs due to the amount of technical equipment and expertise required and difficulties with compliance verification (Khannaa *et al.* 2003, Dosskey *et al.* 2005). However, the magnitude of these costs was unknown. It should be noted that technological innovations such as satellite imagery can decrease monitoring and enforcement costs. Further research would be needed to measure and define these transaction costs to better inform policy makers.

Although it was assumed that the compensation amount required for farmers to participate in wetland restoration and maintenance is equal to the mean private costs that are incurred, it is possible that the compensation amount could be less and farmers would still adopt the program especially if farmers find an inherent value in wetlands and riparian areas (Amigues 2002). In addition, program payments represent stable income which may be attractive when compared to highly volatile commodity markets. Thus, perhaps it is preferable to estimate the compensation amount through a process that can capture those benefits and costs not captured by mean opportunity of production. For example a survey instrument using contingent valuation, where farmers are asked their willingness to accept value, may be appropriate. If a lower program payment value can be offered to farmers than the mean opportunity cost value and still be largely accepted by the farm population the cost to the program can be reduced considerably. Therefore, although contingent valuation methods can be quite costly, this can be justified if the willingness to accept value is significantly less than the mean opportunity cost of foregone crop production.

When economic incentives are the only policy tool used to meet objectives the program can become costly. In addition, the use of economic incentives alone diminishes the inherent responsibilities of landowners to provide a socially acceptable level of ecological goods and services (Frey and Oberholzer-Gee 1997, Reeson and Tisdell 2006). An alternative to a strictly economic incentive program involves the use of some form of cross-compliance. Cross-compliance often incorporates a combination of regulation and economic incentive that may be more cost-effective than economic incentives alone. In addition, cross-compliance programs can regulate farmers to provide environmental benefits that are felt by society to be the responsibility of the farmers. For example, in the U.S. swampbuster program, to achieve a mandate of no-net loss of wetlands, support benefits from all government funded farm programs are denied to farmers who plant crops in wetland areas or who drained or altered wetlands after 1985 (EPA 2008). While this study did not provide an in-depth investigation of cross-compliance programs to achieve wetland conservation goals in the PPR, this is a potential area for future research.

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APPENDIX A – RELEVANT LEGISLATION, POLICIES AND TREATIES

Saskatchewan Legislation:
Saskatchewan Wetland Policy (1995)
Natural Resources Transfer Agreement, 1930
Saskatchewan Watershed Authority Act, 2005
Saskatchewan Drainage Control Regulations (2006)
The Conservation Easements Act (1996)
The Environmental Assessment Act (1980)
The Environmental Management and Protection Act, 2002
The Ecological Reserves Act (1980)
The Natural Resources Act, 1993
The Wildlife Act, 1998
The Wildlife Habitat Protection Act (1984)

Canadian Policies & Legislation:
Agriculture Policy Framework (2003)
The Constitution Act, 1867 (The British North America Act, 1867)
The Constitution Act, 1982
Canadian Bill of Rights (1960)
Canadian Charter of Rights and Freedoms (1982)
Canadian Environmental Assessment Act (1992)
Canadian Environmental Protection Act, 1999
Canada Oceans Act (1996)
Canada Wildlife Act (1985)
The Federal Policy on Wetland Conservation (1991)
Fisheries Act (1985)
Income Tax Act of Canada (1985)
Migratory Birds Convention Act, 1994
National Parks Act (2000)
Northwest Irrigation Act (1894)
Species at Risk Act (2003)

International Treaties
Ramsar Convention on Wetlands (1981)
North American Waterfowl Management Plan (1986)
Convention on Biological Diversity (1992)

APPENDIX B - LAND MANAGEMENT SCENARIOS AT CASE STUDY FARMS.

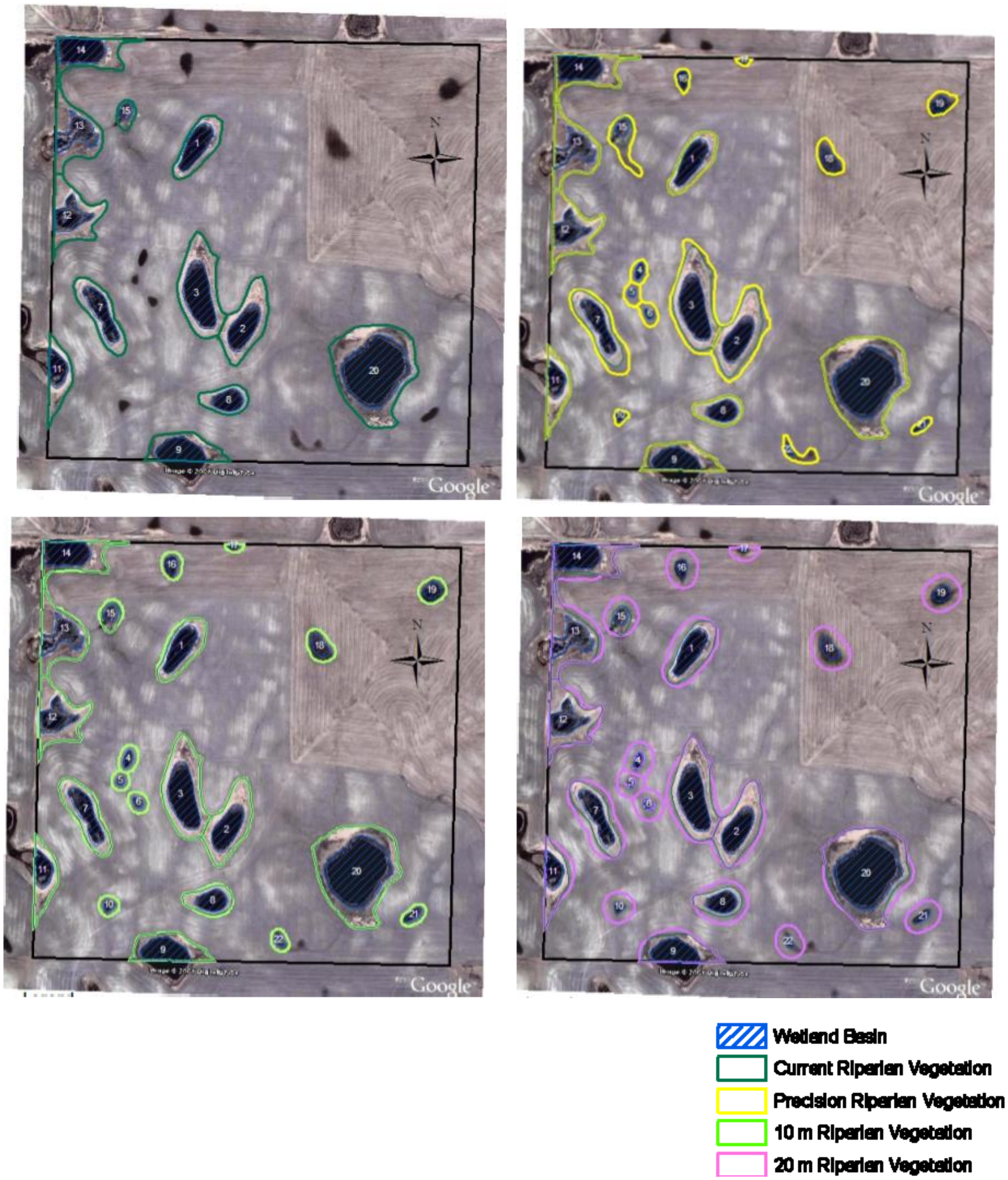


Figure B1 MCI management scenarios when all wetlands targeted.

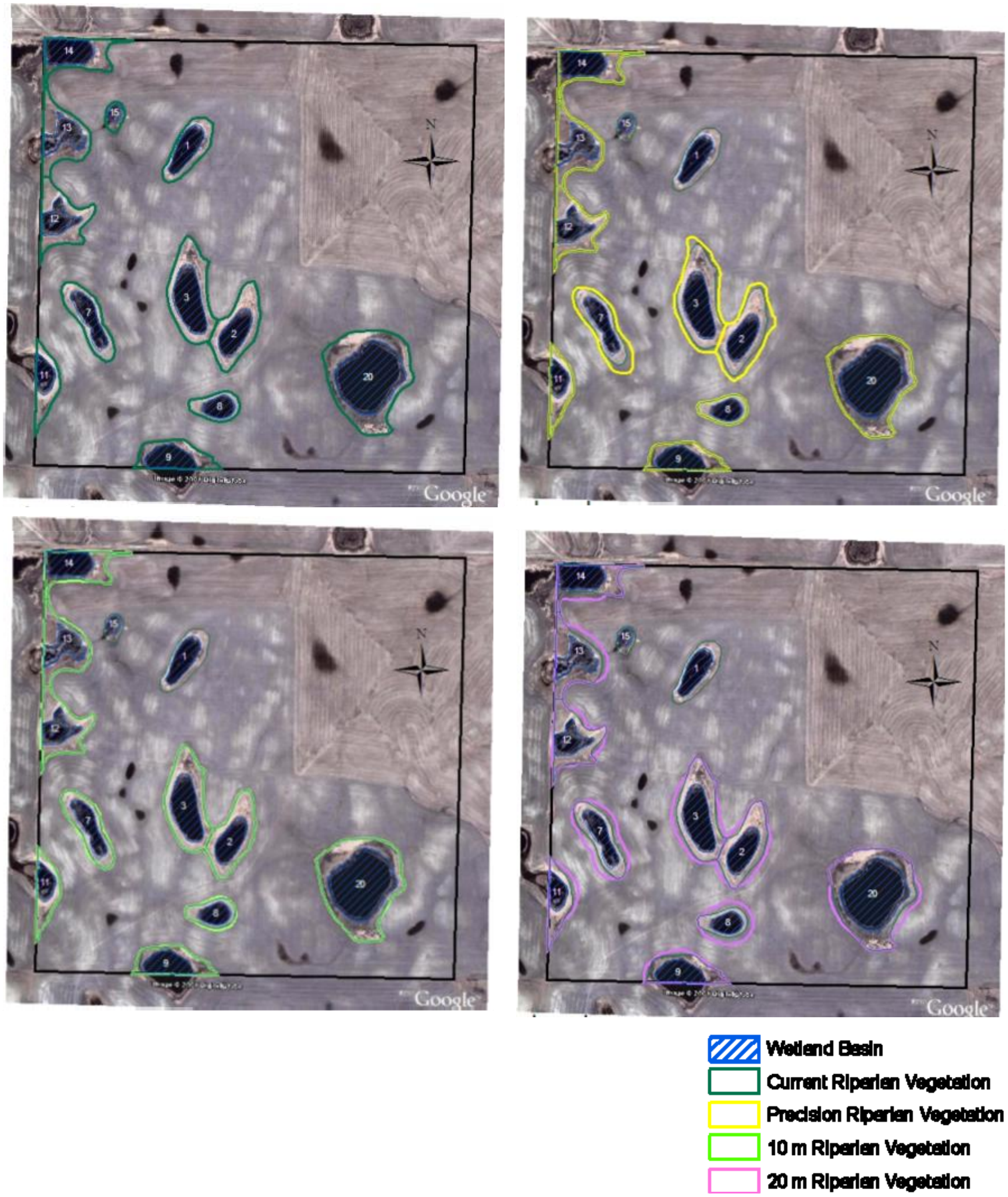


Figure B2 MCI management scenarios when permanent wetlands targeted.

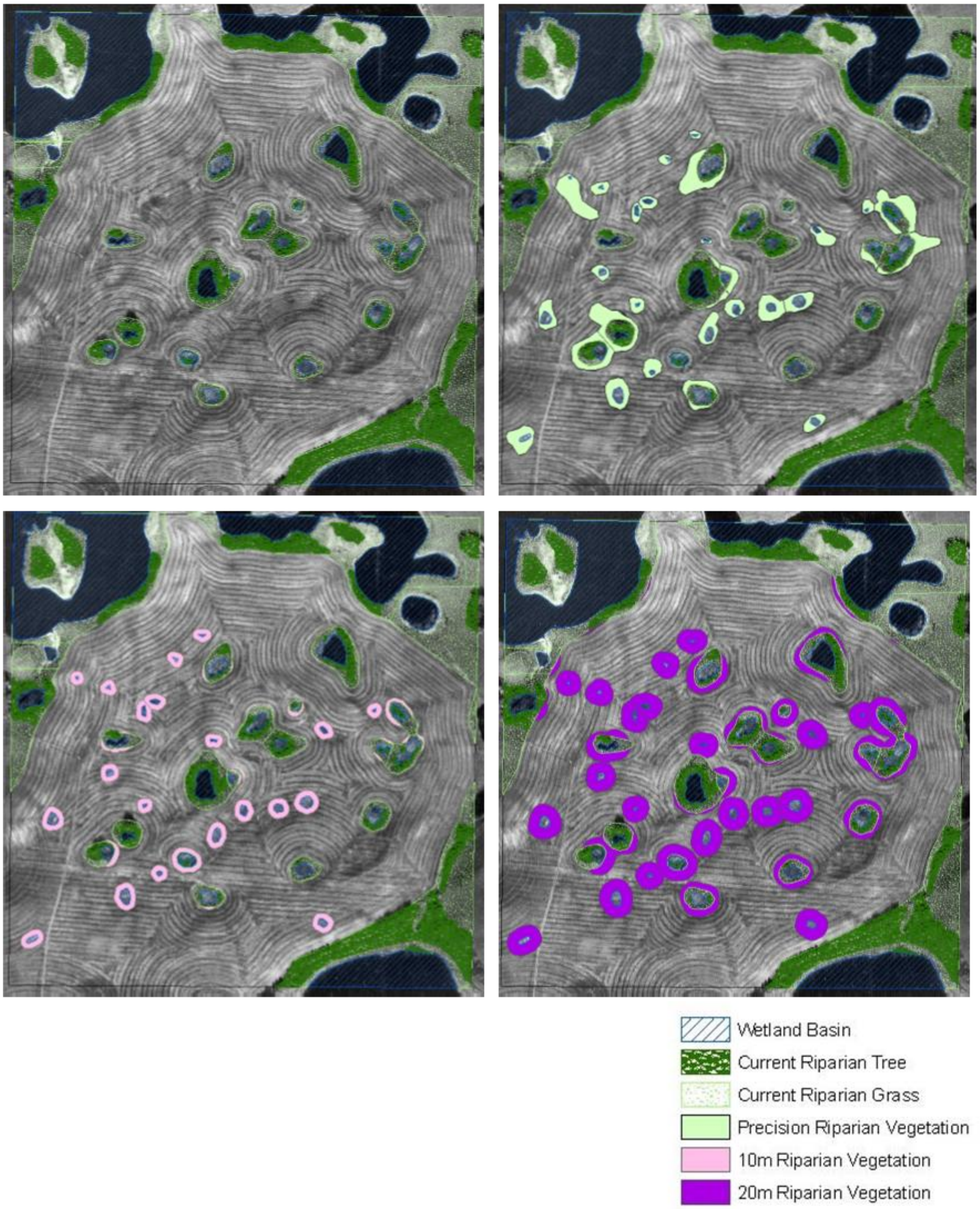


Figure B3 SDNWA management scenarios when all wetlands targeted.

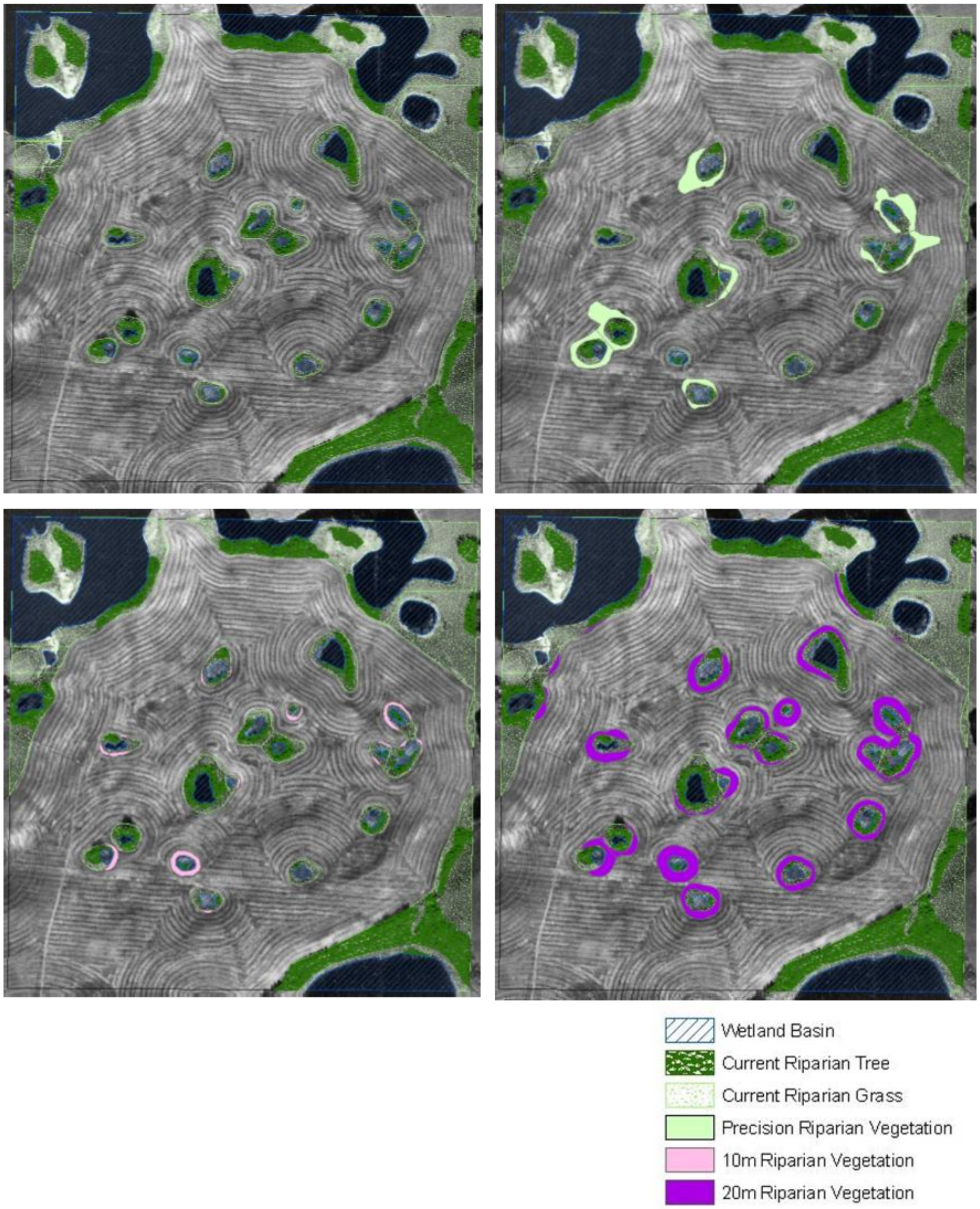


Figure B4   SDNWA management scenarios when permanent wetlands targeted.

Table B1 Total area (ha) in cropland, wetland basin and riparian areas and the carbon sequestered under different management scenarios over a 10 year period.

Management Scenario	MCI				SDNWA			
	Basin Area	Rip. Area	Crop Area	Land Use Δ	Basin Area	Rip. Area	Crop Area	Land Use Δ
No Change	4.5	5.2	55.1	0.0	7.8	13.3	45.1	0.0
All wetland Precision riparian (1a)	4.9	7.0	52.9	2.2	8.1	16.4	41.8	3.3
All wetlands Riparian-10m (1b)	4.9	6.4	53.4	1.7	8.1	15.3	42.9	2.2
All wetlands Riparian-20m (1c)	4.9	9.9	49.9	5.2	8.1	20.2	38.0	7.1
Permanent wetlands Precision riparian (2a)	4.5	5.9	54.3	0.8	7.8	13.4	45.1	0.0
Permanent wetlands Riparian - 10m (2b)	4.5	5.3	55.0	0.1	7.8	13.3	45.1	0.0
Permanent wetlands Riparian - 20m (2c)	4.5	6.8	53.4	1.7	7.8	13.6	44.8	0.3

Table B2 Present value opportunity cost of minimum, maximum and mean production over a 10 year period on restored riparian areas (discount rate (r) = 5%).

Management Scenario	MCI			SDNWA		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
	($)			($)		
No Change	0.00	0.00	0.00	0.00	0.00	0.00
All wetland Precision riparian (1a)	-587.57	2757.52	1256.62	-3101.84	5642.98	3029.32
All wetlands Riparian-10m (1b)	-440.66	2068.08	942.44	-2044.32	3719.09	1996.52
All wetlands Riparian-20m (1c)	-1373.92	6447.96	2938.38	-6596.92	12001.35	6442.68
Permanent wetlands Precision riparian (2a)	-206.47	969.01	441.58	-11.87	21.60	11.59
Permanent wetlands Riparian - 10m (2b)	-35.08	164.66	75.04	0.00	0.00	0.00
Permanent wetlands Riparian - 20m (2c)	-445.79	2092.15	953.41	-280.74	510.74	274.18

APPENDIX C – ETHICS APPROVAL LETTER

UNIVERSITY OF SASKATCHEWAN

Behavioural Research Ethics Board (Beh-REB)

Certificate of Approval

PRINCIPAL INVESTIGATOR	DEPARTMENT	BEH#
Ken W. Belcher	Agricultural Economics	07-129

INSTITUTION(S) WHERE RESEARCH WILL BE CONDUCTED (STUDY SITE)
University of Saskatchewan
Saskatoon SK

STUDENT RESEARCHERS
Amber Cuddington, Jia (Mandy) Yu

SPONSOR
DUCKS UNLIMITED CANADA
ADVANCING CANADIAN AGRICULTURE AND AGRI-FOOD SASKATCHEWAN (ACAAFS)

TITLE
Economic, Greenhouse Gas and Policy Implications of Riparian Management on an Agricultural Landscape

APPROVAL DATE	EXPIRY DATE	APPROVAL OF:
26-Jun-2007	25-Jun-2008	Application Invitation Letter Consent Form Questionnaire

CERTIFICATION
The University of Saskatchewan Behavioural Research Ethics Board has reviewed the above-named research project. The proposal was found to be acceptable on ethical grounds. The principal investigator has the responsibility for any other administrative or regulatory approvals that may pertain to this research project, and for ensuring that the authorized research is carried out according to the conditions outlined in the original protocol submitted for ethics review. This Certificate of Approval is valid for the above time period provided there is no change in experimental protocol or consent process or documents.

Any significant changes to your proposed method, or your consent and recruitment procedures should be reported to the Chair for Research Ethics Board consideration in advance of its implementation.

ONGOING REVIEW REQUIREMENTS
In order to receive annual renewal, a status report must be submitted to the REB Chair for Board consideration within one month of the current expiry date each year the study remains open, and upon study completion. Please refer to the following website for further instructions: *http://www.usask.ca/research/ethical.shtml*

John Rigby

John Rigby, Chair
University of Saskatchewan
Behavioural Research Ethics Board

June 28/07

Signature Date

Please send all correspondence to:

Ethics Office
University of Saskatchewan
Room 306 Kirk Hall, 117 Science Place
Saskatoon SK S7N 5C8
Telephone: (306) 966-2084 Fax: (306) 966-2069

APPENDIX D - SURVEY

UNIVERSITY OF SASKATCHEWAN

Department of Agricultural Economics
51 Campus Drive, Saskatoon, SK
S7N 5A8 Canada
Telephone: (306) 966-4008
Fax: (306) 966-8413

July 2007

Dear Producers;

You are invited to participate in a study entitled "Economic, Greenhouse Gas and Policy Implications of Riparian Management on an Agricultural Landscape". Please read this letter carefully and feel free to ask any questions that you might have.

The purpose of the research is to determine the costs and benefits of implementing beneficial management practices (BMPs) that improve the quantity and quality of riparian areas and natural corridors on agricultural landscapes. Your responses will help us to determine a pattern of program delivery that is cost effective and will be attractive to farmers. It is expected that the survey should take between 10 - 15 minutes to complete.

This research is funded by Ducks Unlimited Canada in conjunction with Advancing Canadian Agriculture and Agri-Food which is an organization dedicated to finding policy solutions that directly benefit Canadian farmers and the agriculture and agri-food industry. The research conclusions will be published in a variety of formats, both print and electronic. These materials may be further used for purposes of conference presentations, or publication in academic journals, books or popular press.

Participation in this survey poses no personal risk. Data and information provided by surveys will be reported in an aggregate form that protects the confidentiality and the anonymity of individual participants. In principle, actual names will not be used. The survey data will be securely stored by the Research Advisor, Dr. Ken Belcher, at the Department of Agricultural Economics for a period of five years. This information will only be available to the Researchers for the purpose of this study. Your participation is completely voluntary and you may withdraw from the study for any reason, at any time, without penalty. You may also refuse to answer individual questions. Return of the survey questionnaire to the Researcher's indicates your consent to participate in this study.

If you have any questions concerning the study, please feel free to ask at any point by contacting the Researchers at the numbers provided below. This study has been approved on ethical grounds by the University of Saskatchewan Behavioural Research Ethics Board on June 26th, 2007. Any questions regarding your rights as a participant may be addressed to that board through the Ethics Office (306-966-2084). Out of town participants may call collect.

To thank you for participating in this survey we invite you to enter into a prize draw of your choice for a handheld GPS, or Satellite Radio system. Only participants who have returned a completed survey are eligible for the prize draw. Entry into the prize draw is completely optional. The lottery draw form will be stored separately from the survey, further preventing the identification of individual participant's responses.

Researchers:

Ms. Amber Cuddington
Center for Studies in Agriculture, Law & the Environment
University of Saskatchewan
(306) 966-1692

Ms. Mandy Yu
Dept. of Agricultural Economics
University of Saskatchewan
(306) 966-4034

Dr. Ken Belcher
Dept. of Agricultural Economics
University of Saskatchewan
(306) 966-4019

Figure D1 Survey letter of invitation.

UNIVERSITY OF SASKATCHEWAN

Economic, Greenhouse Gas and Policy Implications of Riparian Management on an Agricultural Landscape

Researchers
Amber Cuddington (306) 966-1692
Mandy Yu (306) 966-4034
Ken Belcher (306) 966-4019
Department of Agricultural Economics, University of Saskatchewan, 51 Campus Drive, Saskatoon, SK, S7N 5A8

How to Complete this Questionnaire

- Please read through the letter of invitation prior to completing the questionnaire.
- Please ensure that only 1 questionnaire is completed for each agricultural operation.
- Gray text indicates directions to answering the question or direction to the next questions to be answered.
- When answering the questionnaire please consider only the practices related to the land that was operated by you in 2006, do not report on land that you rented or leased to others.
- Definitions of important terms are included on the back page. If a definition is provided it will be indicated in the text by a superscripted number (example: conventional tillage[1]).
- Fill out the questionnaire using a black or blue pen.
- Enter a number in a box ,example: 1 2 3 4
- Fill in a box , example: ☑ or ☒
- Print on a line, example: *cultivator*

Once Completed

- If you are satisfied with your responses please mail the completed questionnaire in the provided postage paid envelope, return of the prize draw entry form is optional.
- If you have any questions, comments or concerns please contact the researchers.
- **Your responses are strictly confidential and will be used only for statistical purposes.**

Part I. General

Question 1
What RM is your farm located in? RM# ________

Question 2
Is the cropping portion of your farm certified organic?
☐ Yes
☐ Partially, what proportion? __________ %
☐ No

Question 3
What type of farm operation do you have?
☐ Grain
☐ Mixed Grain & Cattle, Grain_____% Cattle_____%
☐ Other (Specify) _________________

Part II. Cropping & Land Us Information

Question 4
What is a typical 5 year crop rotation or any given field on this farm? (If you commonly use 2 different rotations include both, for example one commercial rotation and one seed production rotation)

Year 1	Year 2	Year 3	Year 4	Year 5
______	______	______	______	______
______	______	______	______	______

Question 5
Approximately how much area was dedicated to each of the following crop types in 2006?

Cereals	☐☐☐☐☐	Acres
Pulses	☐☐☐☐☐	Acres
Oilseeds	☐☐☐☐☐	Acres
Tame Hay/Silage	☐☐☐☐☐	Acres
Other, ________	☐☐☐☐☐	Acres

Question 6
What type of tillage practice did you use on this farm in 2006?
☐ Conventional Tillage[1]
☐ Conservation Tillage[2], year implemented _________
☐ Zero-tillage[3], year implemented ___________

Question 7
Approximately how much area was dedicated to each of the following land uses in 2006?

	Owned	Rented or Leased	
Cropped	☐☐☐☐☐	☐☐☐☐☐	Acres
Summerfallow[4]	☐☐☐☐☐	☐☐☐☐☐	Acres
Tame Forage[5]	☐☐☐☐☐	☐☐☐☐☐	Acres
Native Pasture[6]	☐☐☐☐☐	☐☐☐☐☐	Acres
Woodlands[7]	☐☐☐☐☐	☐☐☐☐☐	Acres
Wetlands & Riparian Areas[8]	☐☐☐☐☐	☐☐☐☐☐	Acres
Permanent Veg. Corridor[9]	☐☐☐☐☐	☐☐☐☐☐	Acres

Question 8
What kind of tractor and implement do you typically use for the following management practices? (If you apply fertilizer at seeding please indicate this in the fertilizer row)

	Tractor HP	Implement	Width (ft)
Seeding	☐☐☐	__________	☐☐☐
Tillage	☐☐☐	__________	☐☐☐
Fertilizer	☐☐☐	__________	☐☐☐
Pesticides	☐☐☐	__________	☐☐☐

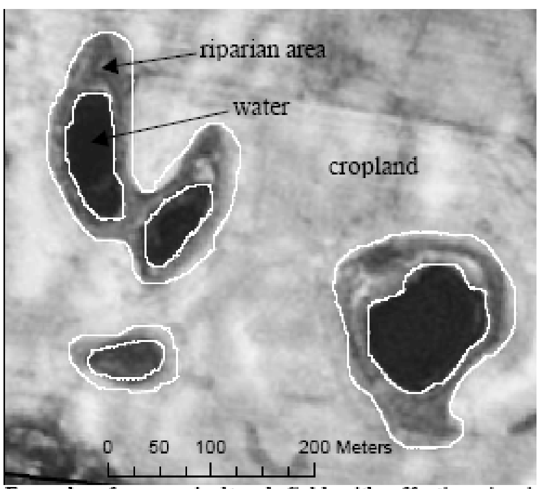
Figure D2 Survey questionnaire.

Part III. Wetland & Riparian Management

Definition Riparian Area - Permanent vegetation (including native species, tame forages and shrubs) that is adjacent to any body of water (permanent[10] or seasonal[11]) – see photo below.

Question 9
We are investigating the feasibility of a riparian management program aimed at restoring and maintaining riparian zones in the agricultural regions of Western Canada. The proposed program would provide financial and technical assistance to farmers who provide permanently vegetated riparian zones around wetlands (minimum 10 meters or 32 feet wide) within agricultural fields. The proposed program would consist of a 10 year contract that provides landowners with an annual payment based on the area of land allocated to riparian vegetation. At the end of the contract period the landowner could choose to renew the contract or exit the program. For the duration of the contract the subject riparian zone could not be cultivated or cropped , however, the areas could be managed for haying or grazing at pre-determined times during the growing season. If the area is disturbed by cultivation or cropping during the contract period the landowner would be responsible for reimbursing the program payment.

The program would provide farmers with an annual $10 per acre payment based on the area that is allocated to permanent riparian vegetation. Would you accept this program payment to restore and/or maintain riparian areas around wetlands on your land?
☐ Yes ☐ No



Example of an agricultural field with effective riparian areas.

Question 10
Have you drained/cultivated wetlands or pushed-bush on your farm within the last 10 years?
☐ Yes ☐ No

Question 11
Do you plan to drain/cultivate wetlands or push-bush on your farm land within the next 5 years?
Yes ☐ No

Question 12
Do you maintain a riparian area surrounding water bodies that hold water throughout the summer in most years (ie. permanent wetlands[10])?
☐ Yes → Minimum Width ________ ☐ feet ☐meters
☐ No

Question 13
Do you maintain a riparian area surrounding water bodies that hold water until mid-may in most years (ie.seasonal wetlands[11])?
☐ Yes → Minimum Width ________ ☐ feet ☐meters
☐ No

Question 14
Please indicate the level to which you agree with the following statements: (A=Agree ; N=Neutral; D=Disagree)

	A	N	D
Riparian areas harbor undesirable pests	☐	☐	☐
Riparian areas are pleasing to look at	☐	☐	☐
Riparian areas are important for erosion control.	☐	☐	☐
Riparian areas reduce farm productivity..........	☐	☐	☐
Riparian areas are important for water quality...	☐	☐	☐
Riparian areas are important for flood control...	☐	☐	☐
Riparian areas are costly to maintain...............	☐	☐	☐
Riparian areas are important for wildlife..........	☐	☐	☐
Riparian areas are difficult to maneuver around with farm equipment.....................	☐	☐	☐
The benefits of wetlands and riparian zones outweigh the disadvantages.....................	☐	☐	☐

Part IV. Farm Planning

Question 15
Do you have a defined farm management plan for your farm?
☐ Yes ☐ No (If no, please proceed to question 18)

Question 16
What components does your farm management plan address? (check all that apply)
☐ Crop rotation
☐ Fertilizer use
☐ Pesticide use
☐ Budget

Question 17
How long does your plan extend?
☐ Less than five years
☐ 5-10 years
☐ Greater than 10 years.

Question 18
Have you conducted an Environmental Farm Plan[12] (EFP)?
☐ Yes ☐ No (If no, please proceed to question 24)

Question 19
Why have you chosen to complete an EFP?(check all that apply)
☐ Interest in the Environment
☐ To access funding
☐ Believe they will be mandatory in the future
☐ Encouragement from other farmers/neighbors
☐ Other, specify________________________

Question 20
When was your EFP developed or last updated?
☐ Less than 1 year ago
☐ 1-5 years ago
☐ More than 5 years ago

Question 21
To what extent have you implemented beneficial management practices[13] (BMPs) outlined in your EFP?
☐ Fully implemented
☐ Partially implemented
☐ Not implemented

Question 22
Have you received any technical assistance to help implement BMPs? (check all that apply)
☐ No
☐ Yes, from a government agency
☐ Yes, from a private industry agency
☐ Yes, from a private environmental/conservation agency
☐ Yes, from other, specify________________________

Question 23
Have you received any financial assistance to offset the costs of implementing BMPs?
(check all that apply then proceed to question 26)
☐ No
☐ Yes, from a government agency
☐ Yes, from a private industry agency
☐ Yes, from a private environmental/conservation agency
☐ Yes, from other, specify________________________

Question 24
If you have not completed an EFP please identify the reasons. (check all that apply)
☐ Have never heard of this program
☐ Have not had time
☐ Too much paper work involved
☐ Do not feel a need to manage for the environment
☐ Disagree with this government program
☐ Other, specify ________________________

Question 25
Do you plan to conduct an EFP in the future?
☐ Yes ☐ No

Part V. Farm Operator Profile

Question 26
How long has the oldest part of your farm been in your family? ______ years

Please answer the following questions for EACH PERSON responsible for making management decisions on this farm.

Operator 1

Question 27
What is your age? _______ years

Question 28
How long have you been a decision maker on your farm?
_____ years

Question 29
What is the highest level of education you have received?
☐ Primary/Secondary School
☐ High School Diploma
☐ College/Journeyman Diploma
☐ Bachelor's Degree
☐ Graduate Degree

Question 30
Do you have any off-farm income?
☐ Yes ☐ No

Question 31
How long do you plan to continue farming? ________ years

Question 32
If you are planning on retiring in the next 10 years will someone in your family take over farm management when you retire?
☐ Yes
☐ No
☐ Don't know

Operator 2

Question 33
What is your age? _______ years

Question 34
How long have you been a decision maker on your farm?
_____ years

Question 35
What is the highest level of education you have received?
☐ Primary/Secondary School
☐ High School Diploma
☐ College/Journeyman Diploma
☐ Bachelor's Degree
☐ Graduate Degree

Question 36
Do you have any off-farm income?
Yes ☐ No

Question 37
How long do you plan to continue farming? ________ years

Question 38
If you are planning on retiring in the next 10 years will someone in your family take over farm management when you retire?
☐ Yes
☐ No
☐ Don't know

If there are more than 2 people that make management decisions on your farm please provide their details in the comments section.

Thank you for taking the time to complete this survey!
If you have any additional comments please feel free to provide them in the comments section on the back of this page.

"Economic, Greenhouse Gas and Policy Implications of Riparian Management on an Agricultural Landscape"
Prize Draw Entry Form

The prize draw is provided as a "thank-you" for assisting us in our study and is completely optional. This form will be stored separately from the survey thus ensuring your confidentiality. If you have any questions or concerns please call us at 966-1692.

To be entered into the prize draw please provide your name and phone number on the form below and indicate which prize you would prefer. Return this form in the provided postage paid envelope with your completed survey questionnaire. DO NOT staple this form to your survey questionnaire. Your name and contact information will remain confidential and you will only be contacted if you are a prize winner.
Draw to be held on August 31st, 2007

Name: ______________________________________

Phone Number:________________________________

Prize Package

- ☐ **Hand Held Global Positioning System Unit**

or

- ☐ **Satellite Radio System + 1 year subscription**

The value of each prize package is estimated to be $200.

Figure D3 Survey prize draw entry form.

Dear Farmer,

About 3 weeks ago, we sent you a questionnaire for our research study "Economic, Greenhouse Gas and Policy Implications of Riparian Management on an Agricultural Landscape". If you have already filled it out and returned it, please accept our thanks. If you have not gotten to it yet, please take some time to fill out the questionnaire and return it. Your responses to the questionnaire are important because they represent the views of many farmers like yourself and may be used to help guide agricultural policy in the future. If for some reason you did not receive a questionnaire, please contact me and I will send one out right away. Thanks again.

Sincerely,
Amber Cuddington, M.Sc. candidate
(306) 966-1692
adn336@mail.usask.ca

Figure D4 Survey reminder post card.