WATER-RELATED ECOSYSTEM SERVICES AND WATER QUALITY: FARMERS' PERCEPTIONS AND PRACTICES

by

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This thesis is dedicated to my grandfather, the late Kanagamani Periasamy

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ABSTRACT

Freshwater ecosystems provide numerous ecosystem services (ES) to humans. Agricultural pollution negatively impacts waterbodies and their capacity to provide ES. To reduce agricultural pollution it is crucial to understand farmers' perceptions and the different factors that influence farmers' decision-making. This thesis sought to understand farmers' perceptions of water-related ES, climate change, and water quality, and to examine the role of these perceptions in influencing farmer decision-making related to farm water management. Map elicitation interviews were conducted with farmers in Musquodoboit Valley, Nova Scotia. Results suggest that farmers easily identified provisioning and cultural services, while regulating and supporting services were under-recognized. Farmers used management practices to maintain the ES they identified and to reduce disservices. Farmers had high climatic awareness, and some farmers understood the contribution of agriculture to water pollution. Farmers' decision-making was influenced by their perception of ecosystem services and water quality. These results will inform agri-environmental programs.

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CHAPTER 1: INTRODUCTION

1.1 Context

Globally about 1.2 to 1.5 billion hectares of land is being used for cropping activities, and 3.5 billion hectares of land is being used for grazing activities (together occupy 38 % of the earth's terrestrial surface), making agriculture the major land use on earth (Foley et al., 2011). Agriculture is also the major user of freshwater, accounting for about 70% of total global freshwater withdrawals (de Fraiture, Molden, & Wichelns, 2010). It is almost certain that population growth will further increase the demand for food production, and encourage land clearing, water extraction and fertilizer use (Tilman, Balzer, Hill, & Befort, 2011). Agricultural practices negatively impact freshwater ecosystems and their services, through extractive use and nutrient enrichment (Verhoeven, Arheimer, Yin, & Hefting, 2006). Agricultural water management will be further challenged by temperature and precipitation variability brought about by climate change (Mertz, Mbow, Reenberg, & Diouf, 2009; Thomas, Twyman, Osbahr, & Hewitson, 2007). It is therefore critical that agricultural water management practices be modified in ways that allow increased food production without degrading ecosystems and their capacity to deliver services to humans. The issue is no longer limited to identifying efficient agricultural water management practices, but designing policies and programs that will ensure farmer adoption of these practices.

Voluntary programs can be used to encourage farmer adoption of environmentally friendly water management practices. However, the success of voluntary programs is highly dependent on farmers' willingness to participate. Research has demonstrated that farmer decision-making and willingness to participate depends on multiple factors, including farmers' environmental perceptions and awareness (Guillem & Barnes, 2013). It is widely held that there are very few universal factors that explain farmer adoption behaviour (Knowler & Bradshaw, 2007), therefore, it is necessary to investigate locally influential variables. In addition, it is argued that farmers are not passive recipients of knowledge and practices, instead use their experiential knowledge to make decisions (Riley, 2009). Therefore, in order to design successful agri-environmental outreach programs it is necessary to understand the influence of farmers' perceptions and experiential knowledge on decision-making.

1.2 Project Overview

This thesis is primarily concerned with understanding farmer perceptions of ecosystem services and water quality, and the influence of those perceptions on farm water management practices. In addition to investigating farmers' perceptions, this thesis also documents farmers' experiential knowledge and solutions relevant to farm water management. Farmers are regarded as experts in their fields (Riley, 2009) and often develop management practices that best suit local conditions through experimentation. Finally, I will attempt to use my understanding of farmers' perceptions and decision-making to make recommendations for the design and implementation of agri-environmental programs.

This thesis focuses on the small farming community within the Musquodoboit watershed in the province of Nova Scotia in Atlantic Canada. Halifax Water draws water from the Musquodoboit River to supply potable water for 96 residential households and businesses in the village of Middle Musquodoboit (Stea, 2013). In addition, the Musquodoboit River consists of suitable habitat for Atlantic salmon (Watt, Scott, Zamora, & White, 2000) and drains into a series of coastal wetlands identified as internationally important by the RAMSAR convention (Province of Nova Scotia, 2001). Halifax Water manages this source watershed, and has observed poor water quality, including high concentrations of *Escherichia coli* (Stea, 2013) and nitrate levels especially after storm events. It is likely that improper agricultural practices are contributing to poor water quality in the Musquodoboit River (B. Geddes, personal communication, November 6, 2012). Typically, organizations such as Halifax Water and Nature Conservancy Canada protect water resources through acquisition. In this particular situation, these organizations are beginning to engage directly with farmers (B. Geddes, personal communication, November 6, 2012; C. Smith, personal communication, November 6, 2012) to improve agricultural water management and thus water quality in adjacent watercourses and wetlands. The success of such programs requires an in depth understanding of farmer perceptions. This study will use social science research methods, including map elicitation and semi-structured interviews with farmers in order to assess farmers' perceptions and decision-making related to water management. Government and non-government agencies working to promote beneficial agricultural management practices in Nova Scotia will benefit from this research.

1.3 Goals and Rationale for Study

The purpose of this thesis is to examine farmers' perceptions, and their influence on farmers' decision-making regarding water management. Specifically, I examine farmer perceptions of water-related ecosystem services, climate change and water quality and how these factors influence farm water management decisions.

The primary research question of this thesis is:

1) What are farmers' perceptions of water-related ecosystem services, and how do these perceptions influence decision-making surrounding water management?

The goal of exploring this research question is to understand how farmers attribute services and disservices to water bodies. Ecosystem services refers to the benefits humans obtain from ecosystems (MEA, 2005). The ecosystem services concept serves as a bridge connecting ecosystem processes and human benefits (Braat & de Groot, 2012). It is expected that farmers would manage their land in ways that reflect their perceptions of the environment, to maximize benefits and minimize costs derived from the ecosystem.

The thesis will also answer the following sub-questions:

2) What are the different farm water management practices farmers use to manage the services and disservices arising from water bodies?

The goal of this question is to understand existing management practices, and farmers' rationale for using these practices. Shedding light on existing practices will help us understand the socio-economic and cultural factors that influence adoption of farm water management practices. For the purposes of this study, farm water management will be defined as the efficient use of available water to meet agricultural needs (modified from Ali, 2011, p.140). The following categories will be considered (modified from Delaney, 2012, p. 20): 1) soil and water conservation activities; 2) irrigation practices; and, 3) drainage.

3) What are farmers' perceptions of climate change, and how do those perceptions influence their water management decisions?

Uncertainty and variability are key components of climate change projections in Atlantic Canada (Hennessey & Dollin, 2007), and will likely make farm water management much more challenging. It is anticipated that climate change will bring increased temperatures, precipitation, and extreme weather events to Atlantic Canada (Lines, 2010). Farms within the Musquodoboit watershed are particularly vulnerable to inland riverine flooding following high precipitation events (Burrell, 2011). Since climate change has the potential to influence water quantity and quality on farms, it is important to understand farmers' perceptions of climate change and how it influences farm-level water management practices.

4) What are farmer perceptions of water quality within the Musquodoboit watershed, and how do they perceive the impacts of their agricultural practices on water quality?

It is important to know if farmers recognize the connection between their on-farm water management practices and water quality issues within the watershed. Most environmental educational programs operate under the assumption that if landowners understand the impact of their practices on water bodies, they will be more willing to adopt farm management practices that will reduce their impact (Macgregor & Warren, 2006).

1.4 Structure and scope of Thesis

This thesis is presented in the manuscript format, with six chapters. This general introduction chapter provides context and outlines the purpose of the thesis. Chapter 2 is an in-depth review of the relevant literature. Chapter 2 looks into the following topics: relationship between farming and water resources, the ecosystem services framework and its applicability to research in agriculture, farm management and adapting agriculture to climate change. Chapter 3 describes the research methods used in this entire study. Chapter 4 is in a free-standing manuscript format, focusing on farmer perceptions and decision-making surrounding ecosystem services and climate change (Research questions 1-3). Chapter 5 is presented as a report to Halifax Water and Nature Conservancy Canada, and discusses farmer perceptions of water quality and the contribution of agriculture to water quality impacts within the watershed (Research Question 4). Finally, Chapter 6 puts forward the general conclusions and recommendations that arise from this study.

This thesis is concerned with understanding farmers' perceptions of ecosystem services, water quality, and farm water management practices. The reader should bear in mind that this thesis focuses on the Musquodoboit Watershed in Nova Scotia, Canada and insights and conclusions made are particularly relevant to this watershed and its farmers.

CHAPTER 2: LITERATURE REVIEW

2.1 Water quality in Canada

Freshwater ecosystems such as rivers, streams, lakes, and wetlands have traditionally been central to human settlements. Freshwater ecosystems provide a surfeit of benefits to humans such as provision of water for drinking, irrigation, industry needs, power generation, navigation and recreational purposes (Malmqvist & Rundle, 2002; Naiman & Turner, 2000). The availability and access to water has governed the rise and fall of powerful civilizations and the proper functioning of socio-political and economic systems (Solomon, 2011). It is not surprising that many successful civilizations and major cities have risen and prospered near large river ecosystems (Grey & Sadoff, 2003). Water resources have been heavily modified to better serve human needs. Globally, exploitation of water resources by humans have resulted in freshwater shortages (Gleick, 2012). In addition, freshwater ecosystems are among the most degraded ecosystems in the world (Revenga, Campbell, Abell, de Villiers and Bryer, 2005). Some of the impacts that arise from human activities are: reduction in water quality through discharge of harmful substances, introduction of exotic species, and physical degradation of the aquatic ecosystem (Rapport & Whitford, 1999; Rapport, 1999). Impacts to aquatic ecosystems in turn negatively affects water quantity and water quality and subsequently affects human well-being.

Water resources continue to support our economy. For example, it is estimated that in 1992 the Canadian economy benefitted between $7.5 and $23 billion from its water resources (Bakker & Cook, 2011). Even relatively water rich nations like Canada can face water shortages through improper water management (Bakker & Cook, 2011). David Schindler, a world renowned Canadian scientist, argues that despite the perceived abundance of freshwater resources in Canada, regional variability, existing management practices, and climate warming will lead to a reduction in the availability of freshwater (Schindler & Donahue, 2006). It has been increasingly recognized that water resource management can be most effective if it occurs at the watershed level without being constrained by jurisdictional boundaries (Kenney, 1997; Rapport & Whitford, 1999). Despite being a nation dependant on its freshwater resources, Canada does not have an effective national strategy to establish water security (Bakker & Cook, 2011; Zubrycki, Roy, Venema, & Brooks, 2011). According to the Canadian Constitution Act (1867), the responsibility of managing water resources lies within the power of provincial governments. The approach taken by individual provinces and territories is varied; only eight out of the 13 jurisdictions have legally binding regulations for water quality testing. Thus, water security for Canadians is dependent on an individual Province's policies and actions.

Nova Scotia's economy has been dependent in part on freshwater resources, either directly through resource industries, such as agriculture and forestry, or indirectly through activities such as tourism. The Nova Scotia Government has taken some proactive steps in regards to water resource management. The Nova Scotia drinking water quality water monitoring program is considered to be relatively strict in comparison to other provinces (Zubrycki et al., 2011). Only the provinces of Alberta and Nova Scotia have fully adopted the national guidelines for water quality (Hill et. al., 2007 as cited in Dunn & Bakker, 2011). In addition in 2010, the province created the Nova Scotia water strategy titled "Water for Life: Nova Scotia's Water Resource Management Strategy" which lays down a road map for water management in Nova Scotia for the upcoming 10 years (Province of Nova Scotia, 2010). Despite its best intentions, the Nova Scotia Water Resource Management Strategy has only limited staff and budget to carry out its mandate, so progress towards goals has been slow (Krista Hilchey, personal communication)

In Nova Scotia, health related parameters (microbiological, physical and chemical) are legally enforceable. In Nova Scotia, drinking water quality is tested using the Canadian Drinking Water Quality Guidelines parameters. However, water quality monitoring of watercourses is almost non-existent. Only about five rivers in Nova Scotia are sampled for water quality annually (Steve Doucette, Nova Scotia Environment, December 2, 2014, personal communication). The study site investigated as part of this thesis, the Musquodoboit River, is not among the five rivers being sampled for water quality annually. Due to the lack of systematic water quality monitoring, the state of watercourses in Nova Scotia and its impact on aquatic biodiversity is unknown. Problems attaining safe water quality either arise at the water treatment facility level or at the source water protection level. On average, at any given time about 50 boil water advisories exist within NS and rural water treatments governed by small municipalities are continually at risk of contamination (Nova Scotia Environment, 2012; Fred Wendt, 2010). It has been well established that to provide safe drinking water, a multi-barrier approach needs to be adopted. The multi-barrier approach, begins with protection of source water, implementation of effective water treatment, distribution, and regular and proactive monitoring practices (Mitchell, 2005). This thesis is concerned with the protection of sources of drinking water and freshwater ecosystems, particularly from the impact of agricultural activities.

Voluntary or mandatory approaches can be taken to protect water quality; historically, the agriculture sector has favored voluntary approaches (Alberini & Segerson, 2002). Pollution caused by agriculture continues to be a threat to drinking water sources in Nova Scotia. There are no mandatory riparian buffer zone requirements for agricultural activities in Nova Scotia (Agriculture and Agri-Food Canada and Island Nature Trust, n.d.). In Nova Scotia, municipal land use and zoning by-laws are used to protect source water. In addition, several voluntary programs exist to reduce agricultural pollution. The Environmental Farm Plan and the Nutrient Management Plan are voluntary programs that offer resources and professional advice to assist farmers to become better environmental stewards (Nova Scotia Federation of Agriculture, 2009). Therefore, a major component of source water protection in Nova Scotia involves the success of voluntary agri-environmental programs.

Globally about 1.2 to 1.5 billion hectares of land is being used for cropping activities, and 3.5 billion hectares of land is being used for grazing activities, making agriculture the major land use on earth (about 40% of the terrestrial surface) (Foley et al., 2005; Howden et al., 2007). It is predicted that the historical increase in agricultural production needs to continue to meet the demands of the growing human population (Howden et al., 2007). The increase in global food production is currently supported by high inputs of water and agrochemicals (David, 2007, p.42). It is likely that the human population will continue to increase and thus so will the use of water and agrochemicals in agriculture. It has been widely recognized that agricultural activity is a major contributor to non-point source pollution (Baker, 1992). Point source pollution refers to pollutants that enter water bodies from a definitive source, such as a pipe. By contrast, non-point source pollution refers to pollutants that do not enter water bodies from a definitive source, and can typically be attributed to multiple sources and processes (Xepapadeas, 2011). According to the Environmental Protection Agency (2003, Chapter 1, pp. 1-3) :

> Non-point source pollution generally results from precipitation, land runoff, infiltration, drainage, seepage, hydrologic modification, or atmospheric deposition. As runoff from rainfall or snowmelt moves, it picks up and transports natural pollutants and pollutants resulting from human activity, ultimately depositing them into rivers, lakes, wetlands, coastal waters, and ground water.

The nature of non-point source pollution makes it difficult to control, quantify and take legal action against polluters (Baker, 1992; Gleick, 2012). Agricultural activities, such as livestock trampling and heavy machinery, can cause physical disturbance and directly impact water bodies. Agriculture also releases non-point source pollutants such as nutrients, sediment, animal wastes, salts, and pesticides (EPA, 2003, chapter 2-9) into water bodies.

Agriculture is an important resource sector in Nova Scotia. Presently, the agriculture sector contributes 0.7% of the provincial economy ($222 million annually) (Thibodeau, 2014). Even though the direct economic contribution of agriculture to Nova Scotia’s economy has decreased in recent years, agriculture continues to contribute indirectly in other ways. Agriculture provides social benefits, such as provision of local food, tourism and food security (Devanney, 2007). A major part of Nova Scotian agriculture involves livestock and poultry farms. Improper handling of manure generated from livestock operations can impact water bodies. In addition, traditional agricultural practices in Atlantic Canada include draining of wetlands to get rid of excess water to gain access to arable land (Mackinnon & Scott, 1984 as cited in Province of Nova Scotia & CBCL limited, 2009). Existing agricultural practices in combination with precipitation events such as rainfall or snowmelt can negatively impact water bodies. Small rural communities in Nova Scotia face water quality problems similar to other small jurisdictions, due to contamination of source water by land use activities and inadequate capacity to protect their water sources (Timmer, de Loë, & Kreutzwiser, 2007). In order to minimize the impact of agriculture on water bodies, it is important to understand and improve farm-level and watershed level water management practices.

Historically, water management has focused on improving technological capacity to maximize the extraction and use of water. However, this approach changed following the pivotal Dublin International Conference on Water in 1992, and now water is increasingly considered as an economic good (Organisation For Economic Co-operation and Development, 2010). Following the Dublin Conference, the Global Water Partnership (GWP) was created in 1996 to develop the conceptual framework for Integrated Water Resource Management (IWRM). According to the GWP (Global Water Partnership Technical Advisory Committee, 2000), IWRM is defined as "a process which promotes the coordinated development and management of water, land and related resources in order to maximise economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems." As evident from the definition, IWRM is a more holistic or ecosystem approach to water management that recognizes the social and economic value of water (Mitchell, 2005). More recently, the Ecosystem Service (ES) framework is being used to complement and in some cases as a substitute for the Integrated Water Resource Management approach (Cook & Spray, 2012). The ES framework is used to understand benefits, and trade-offs to gain support for decision-making (Liu, Crossman, Nolan, & Ghirmay, 2013). There are three major criticisms directed at IWRM: the lack of a consistent definition and related ambiguity, the inability to explain the role of society's influence on water management, and the failure to incorporate IWRM into governance (Cook & Spray, 2012). It is hoped by many that the ES framework can overcome some of the limitations of IWRM (Cook & Spray, 2012). In the following sections, I describe the ES framework and its applicability to agricultural systems and water management.

2.2 The concept of ecosystem services and its applicability to research on agriculture and water management

The purpose of this section is to review the literature on ecosystem services (ES). The section begins with a discussion on the different approaches and frameworks used by researchers to study ES. The second part moves on to describe in greater detail the use of the ES concept for agricultural and water resource management. A large and growing body of literature has investigated and applied the concept of ES. There has been considerable interest in cataloguing services provided by ecosystems since the late 1970s (Westman, 1977). In recent years, the ES concept is increasingly being used to support natural resource management decisions. The literature offers multiple complementary ways to define the term ES. Fisher and colleagues (2009) list three commonly used definitions of ES. Daily (1997), as cited in Fisher et al. (2009), defines ES as "the conditions and processes through which natural eco-systems, and the species that make them up, sustain and fulfill human life". According to Costanza (1997), "ES are the benefits humans derive from the functioning of ecosystems". The Millennium Ecosystem Assessment (MA hereafter) (MA, 2005) provides a broader definition and refers to ES as, "the benefits people obtain from healthy ecosystems".

The MA was initiated by the United Nations to better understand the relationship between human well-being and ecosystems and to use this understanding in decision making (Millennium Ecosystem Assessment, 2005). The MA (MA, 2005) puts ES into four broad categories of provisioning, regulating, supporting and cultural services (described below):

- Provisioning services refer to the products obtained from ecosystems including food, freshwater and fuel;
- Regulating services are the benefits human obtain from the self-regulation of ecosystems (described in detail in section 2.3);

- Cultural services are the non-material benefits obtained from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences; and,
- Supporting services are the services that are necessary for the production of all other services. Some examples of supporting services include soil formation, photosynthesis, primary production and nutrient cycling.

Despite the usefulness of the MA classification, it has limitations and the framework cannot be applied to all enquiries. Researchers have designed alternate frameworks to conduct economic valuation of ES (e.g., Costanza et al., 1997; de Groot, Wilson, & Boumans, 2002), to support biodiversity conservation (Wallace, 2007), and for landscape management and valuation (de Groot, Alkemade, Braat, Hein, & Willemen, 2010). For reasons of brevity, these frameworks will not be discussed in detail as part of this thesis. Instead, I will discuss the major differences between the frameworks and the limitations of the MA framework. The conceptual framework put forth by de Groot, Wilson and Boumans (2002) differs from the MA framework in that it considers both regulating and habitat functions to be essential for the delivery of provisioning and cultural services. Habitat function refers to the ability of natural ecosystems to provide habitat for different species to survive and reproduce (de Groot et al., 2002). However, both frameworks (MA, 2005 and de Groot et al., 2002) allow overlap between ecosystem functions and services, which can lead to double counting of some services. Double counting occurs when a service is valued at two stages of economic valuation.

Several frameworks have attempted to address this issue of double counting by differentiating between intermediate and final services. Boyd and Banzhaf (2007) created a classification system for environmental accounting that explicitly differentiates between intermediate ecological components, final services, and benefits. This classification system values only final services and defines them as services that are directly enjoyed, consumed or used by humans. Intermediate ecological components are defined as the processes that generate the final ES. Similarly, Fisher et al. (2008) also argue that distinguishing between intermediate and final services prevents double counting.

In this thesis, I use the MA's definition and classification of ES as a starting point and add elements to the classification to best fit my study. The MA classification was chosen since it is broad, widely used, recognized, and has been previously used as a tool to engage with diverse stakeholders (Folke, Fabricius, Cundill, & Schulze, 2005). Apart from the issue of double counting, the MA classification presents a few other limitations. Firstly, the MA classification does not explicitly identify specific human beneficiary groups. A beneficiary-based approach emphasizes the social components of ES and also avoids the issue of double counting (Rounsevell, Dawson, & Harrison, 2010; Villa et al., 2014) by focusing only on the services that directly provide a benefit. Secondly, the framework focuses only on the positives humans gain from ecosystems and neglects the disservices from nature. Disservices are costs humans incur from ecosystem processes (Lyytimäki & Sipilä, 2009), such as flooding and pests. In this thesis, we explicitly identify human beneficiary groups and disservices incurred to them. Identifying beneficiaries and disservices is important for understanding stakeholder perceptions, and for ES management.

Following the foundation laid by the MA, there has been a large volume of published studies on the concept of ES (Costanza & Kubiszewski, 2012; Costanza et al., 2014) . The ES concept has played a central role in the field of ecological economics, and economists have used the concept to assign economic values to different ecosystems (Adamowicz, 2004; Costanza et al., 1997). It is argued that assigning economic values to ecosystems will assist us in making better decisions surrounding natural resource management and increase biodiversity conservation. However, the need for and the usefulness of ecosystem valuation is highly contested (Laurans, Rankovic, Billé, Pirard, & Mermet, 2013; Toman, 1998). Moreover, valuing ecosystems is challenging, especially when assigning economic values to non-market benefits such as cultural and regulating services.

The ES concept has also been used to conduct non-monetary valuations. Ecologists have used the concept to improve our understanding of ecological functions that generate services (Claire Kremen & Ostfeld, 2005) and to support biodiversity conservation (Quinn, Brandle, & Johnson, 2013). Social scientists have attempted to use the concept of ES for poverty alleviation (Daw, Brown, Rosendo, & Pomeroy, 2011), to understand stakeholder perceptions (Butler, Skewes, Mitchell, Pontio, & Hills, 2014; Orenstein & Groner, 2014) and to identify socio-economic factors that influence decision-making. The ES concept has connected the fields of ecology, economics, and policy making to balance biodiversity conservation and economic development (Braat & de Groot, 2012). The ES concept serves as a bridging concept (Burkhard, Petrosillo & Costanza, 2010), provides a common language through the ES classification, and promotes discussion and collaboration between practitioners from different fields. In this thesis, the goal of using the MA framework is to communicate farmers' perceptions of ES to academics and policy makers interested in agricultural water management.

There are substantial challenges with incorporating the value of nature in everyday decision making (Daily et al., 2009; Jordan & Russel, 2014). In a few seminal cases, such as watershed protection in New York City and Costa Rica (Postel & Thompson, 2005), the value of nature has been successfully integrated into decision making. However, there is very little documented evidence of the use of ES assessments in decision and policy making (Laurans et al., 2013). Recent work has focused on spanning the gap between ES research and decision-making. Spatial identification of ES and decision-making models are some tools used by researchers to explicitly incorporate ES into decision making. Several studies have mapped the supply and demand of ES at various scales (global, national and local) to quantify ES in a spatially explicit manner (Costanza et al., 2014; Crossman et al., 2013). In addition, some researchers acknowledge the movement of ecosystem services and investigate the supply, demand and flow of ecosystem services across space and time (Bagstad, Johnson, Voigt and Villa, 2013). Other researchers have created decision-making tools, such as the 'Integrated Valuation of ES and Tradeoffs' (InVEST) (Daily et al., 2009), and the 'ARtificial Intelligence for Ecosystem Services' (ARIES) (Villa et al., 2014), that can help stakeholders to incorporate ES valuation into decision making. However, most existing research using the ES concept focuses mostly on ecological and economic assessments while social assessments have been limited (Orenstein & Groner, 2014).

Non-economic social assessments can provide useful insights into stakeholder perceptions of ES. Social approaches to ES assessments provides several advantages. According to Orenstein and Groner (2014) social approaches can

1) Improve valuation of cultural ES;
2) Improve our understanding of complex socio-ecological systems;
3) Assure policy relevance by identifying and integrating stakeholder perceptions; and,
4) Strengthen the policy relevance of ES assessments.

Overall, social ES assessments can bring out stakeholders' knowledge and perceptions and assist us to make better decisions. Understanding stakeholder perceptions is particularly important in the context of agricultural water management. Agricultural systems are unique in that farmers are individually responsible for decision-making and there are very few regulations that dictate agricultural practices. In addition, voluntary agricultural policies are commonplace to protect water quality. Therefore, understanding farmer perceptions of water related ES is crucial for agricultural water management.

The relationship between agricultural systems and ES is complex. Agricultural systems depend on a variety of ES (Zhang, Ricketts, Kremen, Carney, & Swinton, 2007a) and in turn provide humans with a set of ES and disservices. Specifically, agriculture is dependent on provisioning services (such as the provision of freshwater for irrigation), supporting services (such as the enhancement of soil fertility) and regulating services (such as water purification by wetlands) from the ecosystem. Using these ecosystem services agriculture provides us with provisioning services (such as food, fuel and fiber) and sometimes cultural services (such as rural and agricultural tourism). Overall, it is widely held that all agricultural systems deliver provisioning services. However, de Groot and colleagues (2002) hold the view that farming practices that rely on auxiliary inputs (abiotic resources) rather than mere functioning of the ecosystem (such as subsistence farming) do not deliver provisioning services. Despite this disagreement, it is well known that all agricultural systems, whether intensive or extensive, require a basic level of ecological functioning to maintain the biophysical capacity of the land (Wood, Sebastian

& Scherr, 2000). Interactions between farming and ecosystems are not always positive, however: farmers incur costs from the functioning of certain ecosystems and agriculture can negatively impact ecosystem function and the delivery of ES (Dale & Polasky, 2007; Zhang et al., 2007). Habitat loss and non-point source pollution are major disservices from agriculture to surrounding ecosystems. Competition from natural ecosystems including weed and pest damage are some common disservices from ecosystems to agriculture (Zhang et al., 2007).

ES trade-offs occur when the delivery of one ES is enhanced at the expense of another ES (Raudsepp-Hearne, Peterson, & Bennett, 2010). Much research has focused on cataloguing and valuing the ES associated with agriculture (Swinton, Hamilton, Lupi & Robertson, 2007). The negative impacts of agricultural production on ES have also been well documented (Zhang et al., 2007). Researchers have also investigated ES trade-offs that occur in agricultural systems. For instance, agricultural systems focused on enhancing provisioning services will have reduced capacity to provide regulating services, such as nutrient cycling and flood protection, and cultural services, such as eco-tourism. Robertson and Swinton (2005) state that increasing agricultural productivity and maintaining environmental integrity is " a grand challenge for agriculture". Several solutions have been suggested to improve ES delivery from agricultural systems, mostly involving market incentives and government regulations (Lant, Ruhl, & Kraft, 2008). Some researchers hold the view that cooperative solutions, where farmers work together, are key to enhance ES delivery (Stallman, 2011).

One approach is to identify 'win-win' scenarios, where farmers benefit through increased agricultural productivity and the public benefit through improvement of other ES. Some studies have looked at a variety of management practices and their capacity to improve agricultural productivity and delivery of ES simultaneously. In a comprehensive study looking at over 280 farm-level interventions in developing countries, Pretty et al. (2006) identified some small-scale interventions that can enhance multiple ES, such as carbon sequestration and water quality, and increase crop yield. An exhaustive literature review by Kremen & Miles (2012) compared the impact of conventional farming systems and biologically diversified farming systems on multiple ES. They found evidence supporting the superiority of diversified farming systems in enhancing multiple ES, including but not limited to biodiversity, soil quality, carbon sequestration, and resistance and resilience to climate change. Contradictorily, some studies have demonstrated that ecosystem service management does not always come with positive effects for biodiversity conservation (Macfadyen, Cunningham, Costamagna, & Schellhorn, 2012). It is important to bear in mind that the successful implementation of these management practices often depends on farmer decision-making. Therefore, shedding light on farmer decision-making regarding ES is important. Our knowledge of farmers' awareness and perceptions regarding regulating ES is particularly limited.

Another approach to enhance ES delivery is the use of direct economic incentives such as the Payment for Ecosystem Services (PES). The PES scheme provides financial compensation for local actors (individuals or communities) for providing ES, such as flood mitigation or water purification (Jack, Kousky, Sims, 2008). PES is based on the principle of beneficiary-pays and is often lucrative in cases where the ES provider is poor. As part of the PES scheme, ecosystem services are considered as commodities and they play a larger role in economic decision-making (Gómez-Baggethun, de Groot, Lomas & Montes, 2010). However, there are several technical difficulties in simplifying and assigning market values to ecosystem services. Moreover, it is argued that commodification of ecosystem services brings out ethical issues in regards to the way we perceive and relate to nature (Kosoy & Corbera, 2010).

2.3 The special case of regulating services

Regulating ES was identified by the MA as the least understood yet potentially most valuable ES (MA, 2005). In addition, the MA estimated that 70% of regulating services are being degraded or exploited unsustainably (MA, 2005). Regulating ES are defined as the benefits humans obtain from the self-regulation of ecosystem functioning (MA, 2005). More specifically regulating services are the benefits humans obtain from the ecosystem processes that moderate other phenomena such as erosion, storms, and pollination, etc. Ecosystems regulate themselves through various biogeochemical cycles and biospheric processes (Costanza et al., 1997). Regulating services can be final services, such as climate regulation or serve, as intermediary inputs to other ES, such as the important service of pollination to food provision. Examples of regulating ES include but are not limited to the following:

- Climate regulation (through sequestration or emission of greenhouse gases by natural biogeochemical processes);
- Water flow regulation (spatial and temporal distribution of water is influenced by land cover and water retention capacity of the land);
- Water purification (ecosystems can introduce or remove impurities from aquatic ecosystems);
- Erosion control (through soil retention);
- Disease and pest control (through biological control of pests and pathogens); and
- Pollination (through regulation of the abundance and distribution of pollinators).

Among the variety of regulating services identified by the Millennium Ecosystem Assessment, regulating services that influence water quantity and quality are particularly important to human well-being (Simonit & Perrings, 2011). In addition to being crucial, water regulating services are complex and not well understood. The services of water flow regulation, water purification and waste treatment maintain water quantity and quality. Water flow regulation is a product of complex interactions between climatic factors, species abundance and distribution, and soil characteristics (Ojea, Martin-Ortega, & Chiabai, 2012).Water purification and waste treatment is carried out by the removal of impurities and organic waste by micro-organisms and vegetation, primarily in wetland ecosystems. These services operate across multiple ecosystems and are often spatially separated from the beneficiary (Keeler et al., 2012). For example, forested ecosystems can regulate water flow upstream and provide economic benefits to communities downstream by creating suitable conditions to carry out farming or to operate a hydroelectric plant (Guo, Xiao, & Li, 2000). These characteristics make it particularly difficult to value water regulating ES.

The complex nature of regulating services makes it difficult to understand and value these services. Regulating services are complex, because often times multiple ecosystem processes operate together to provide a single regulating service. For example, climate regulation is achieved through several biogeochemical or biophysical mechanisms, such as surface albedo, evapotranspiration and via source or sink ecosystems. In addition, most regulating services provide public goods that are characterised by non-rivalry and non-excludability. Non-rivalry means the good under consideration is not diminished by multiple users. Non-excludability means it is impossible to exclude people from using the good. Benefits from regulating services are usually free to all users, however they are costly to replace and in some cases non-substitutable by current technology (Müller-Grabherr, Négrel, & Vermaat, 2014; Sutherland & Gardner, 2011). In most cases, regulating services are often recognized only through the services they protect. In addition, it is difficult to identify the positive contribution of regulating services while it is relatively easy to recognize the negative consequences brought about the loss of regulating services (Nedkov & Burkhard, 2012) . For example the regulating service of 'flood protection' is recognized when there is a flooding event that negatively affects human properties and the delivery of other services.

Most regulating services, such as erosion control, disease and pest regulation and nutrient recycling are non-marketed and undervalued (Kumar & Wood, 2010). It is well known that non-marketed benefits are likely to be degraded or lost (MA, 2005), while marketed benefits can shape natural resource management decisions. Within the current economic system, several regulating services do not have an assigned monetary value. However, the regulating service of carbon sequestration has received a lot of attention globally. Previously, carbon sequestration had very little value and was not widely recognized. However, the United Nations Reducing Emissions from Deforestation and forest Degradation (REDD) program created the international carbon market and assigned an economic value to carbon sequestration (Gibbs, Brown, Niles, & Foley, 2007). The REDD program aims at reducing deforestation and subsequently emission rates in developing nations by offering financial incentives. Creating a market for carbon has contributed to a net increase in carbon sequestration globally. This further illustrates the idea that resource management decisions are shaped by marketable ES.

Regulating services maintain environmental quality and provide resilience to ecosystems and human settlements (Rodríguez & Beard, 2006; Villamagna, Angermeier, & Bennett, 2013), and ensure the continued delivery of other ES. Ecological resilience refers to the ability of an ecosystem to maintain its identity and functions when faced with internal change and external shocks and stresses (Cumming et al., 2005). Highly resilient systems are capable of reorganizing after disturbances and they continue to deliver ES. Regulating ES provide resilience by protecting the ecosystem from short-term shocks, stresses and long-term changes. Flood regulating service is a good illustration of a regulating service that protects human settlements by reducing the risk and intensity of flooding. Even though natural disturbances such as flooding and drought negatively impact humans, it is important to note that natural disturbances are an integral component of healthy ecosystems and provide services, such as nutrient replenishment, and regulate population and species diversity (Lytle & Poff, 2004). Ecosystem resilience is particularly important to agricultural ecosystems in a changing climate.

2.4 Climate change in Atlantic Canada & adapting agriculture to climate change

Evidence suggests that climate change can influence the global water cycle in multiple ways (Stocker, Dahe, & Alexander, 2013). Large scale changes to global precipitation patterns resulting from the changing climate can have important societal consequences (Marvel & Bonfils, 2013), especially for communities that are highly dependent on resource sectors (Adger, 2003). Changes to climate in Atlantic Canada has already been documented. Between the years 1948 and 2005, a mean temperature increase of 0.3 degree Celsius has been observed in the region (Pancura & Lines, 2005), with the highest increase observed in the summer months. In addition, there has been a 10% increase in mean precipitation since the mid-twentieth century (Vasseur & Catto, 2008). Climate change projections for Atlantic Canada include an increase in extreme weather events such as winter storms. Such extreme weather will likely bring about changes in wind, temperature and precipitation patterns to Atlantic Canada (Hennessey & Dollin, 2007). Sea-level rise and resulting inland flooding is a common occurrence in Atlantic Canada. Over a period of 15 years, inland flooding affected 57 communities in

Atlantic Canada and has cost over $40 million in damages (Burrell, 2011). Inland flooding can take multiple forms; some common types include open-water flooding due to rainfall and snowmelt, localized flooding resulting from inefficient storm water drainage and high water tables, and flash floods resulting from high-precipitation weather events and flow obstruction (Burrell, 2011). In Nova Scotia, the Musquodoboit River (the focal study area in this thesis), the Sackville and Little Sackville Rivers, East River (Pictou), Antigonish-area rivers, and Truro-area river regions are prone to inland flooding. Simplified, it can be said that the changing climate will likely bring about more varied and extreme precipitation events and patterns to Atlantic Canada, which will likely impact communities.

In Atlantic Canada, it is expected that climate change will bring both new and exciting opportunities and substantial risks to the agriculture sector (Bootsma et al, 2005). It is estimated that heat units and growing degree dates will significantly increase in the future (Bootsma et al, 2005). This increase in average temperature and longer growing season will likely increase productivity for crops such as corn and soybean that prefer the heat. However, the benefits gained by this average improvement could be abated by the increased intensity with which isolated extreme weather events such as flooding & storm events occur (Vasseur & Catto, 2008). The occurrence of extreme events provides an element of surprise and disruptiveness, which could result in significant impacts to rural communities. For the agriculture sector and associated rural communities to adapt to climate change and variability, it is increasingly important to understand current practices and adaptations.

Apart from understanding the bio-physical impacts of climate change, researchers have also attempted to understand the social dimensions of climate change. Climate adaptation is a local phenomenon and depends on decisions made by local communities (Agarwal, 2010). Therefore, it is important to understand the willingness and capacity of individuals and communities to adapt (Adger et al., 2008; Adger, 2003). Agricultural communities are special socio-ecological systems where farming practices are dependent on climatic conditions. Farmers have experience conducting agriculture in various weather conditions. Farmers are generally knowledgeable about climatic conditions and are capable of adapting their practices to climatic variability. However, climate change can present novel challenges to agricultural societies. In recent years, there has been an increasing amount of literature focusing on farmer adaptation to climate change. Several studies have looked into farmer perceptions of climate change and local adaptation strategies, especially in developing countries (Chhetri, Chaudhary, Tiwari, & Yadaw, 2012; Mertz et al., 2009; Thomas et al., 2007). Common findings from these studies reveal that stakeholders had a high level of climatic awareness. To the contrary, Sherren and Verstraten (2012) found a weather awareness among Maritime farmers, but a lack of broader climatic awareness. Moreover, these studies concluded that the key to successful implementation of climate adaptation practices involves combining conventional technological solutions to climate change with farmers' tactical knowledge.

2.4 Farm management and farmer decision making

Agricultural systems are part of larger biophysical, economic, social and political systems (Olmstead, (1970) as cited in Sivakumar & Motha, (2007)). These external systems exert pressure on agricultural operations and influence agricultural decision-making. The farmer plays a central role in decision-making in farm management. There are varying definitions of farm management. Dillon (1980) describes farm management as "the process by which resources and situations are manipulated by the farm manager in trying, with less than full information, to achieve his [or her] goals". Based on this definition, it is evident that there are multiple attributes to farm management and that farmers make decisions based on available information and awareness of resources and situations. Traditional economic theory postulates that profit maximization is the primary goal for farmers and it highly influences their decision making (Gasson, 1973). Research conducted by agricultural economists has garnered evidence that many farmers do manage their farm to maximize profit. However, farmer decision-making and behaviour often deviates from the primary goal of production maximization. Researchers have suggested instead that farmer decision making is complex and is driven by other motivations, including intrinsic and societal motivations (Gasson, 1973).

In his seminal paper, Gasson (1973) investigated farmer motivations for farming, and their goals and values. Gasson found that large-scale farming operations are more likely to be driven by economic motivations in comparison to smaller farmers. Alternatively, small farmers placed greater emphasis on the intrinsic aspects of farming, such as independence and leading a healthy lifestyle. More recently, interest in environmentally-friendly farming has sparked research interest in understanding farmers' environmental attitudes and decision making in regards to environmentally friendly management practices. The motivation for these studies stem from the fact that many agri-environmental programs are voluntary and depend on the farmers' willingness to participate (Wilson, 1996). Researchers investigating farmers' environmental attitudes created farmer typologies, categorizing farmers often based on farmer motivations and or management style. For example, Brodt, Klonsky, & Tourte, (2006) attempted to categorize farmers based on their management styles. They identified three groups; production maximizers, environmental stewards, networking entrepreneurs. As the name suggests, environmental stewards attempted to manage resources in parallel with nature, and placed lesser emphasis on yields and profits. By contrast, production maximizers, primarily considered farming as a business and focused their attention on increasing yields and profits. In addition, farmers in this group did not prioritize conservation within their farm lands. The last group, networking entrepreneurs were highly engaged in off-farm activities and social interaction and did not solely depend on earning a living from the farm. An interesting quality of farmers in this group was that they enjoyed interacting with peers and experts to acquire and share information on farming. This categorization by Brodt et al. (2006) exemplifies a method researchers have used to better understand farmer decision making. Despite the usefulness of these categorizations, there are several other individual farm and farmer characteristics that can affect farmer decision making.

Farmer characteristics (age, farming experience and education) and farm characteristics (farm size, conventional versus organic farming) are factors that can influence farmer decision making. However, the influence of these factors are context dependent and there are very few universal variables that can explain farmer decision making across different scenarios. For example, several studies have demonstrated that higher formal education among farmers can increase adoption of conservation/environmentally friendly practices. However, Ogunlana (2004) and Atari, Yiridoe, Smale, & Duinker (2009) found there was no link between farmers' formal education and their interest in adopting conservation practices and environmental programs. To the contrary, Masangano & Miles (2004) investigated farmer adoption in Malawi and found that farmers with lower formal education were more likely to adopt a new dry bean variety in comparison to farmers with higher formal education. Masangano & Miles (2004) hypothesized that the observed results were possibly because more women farmers adopted the dry bean variety and women in the region tend to have lower formal education. These contradictory results indicate that adoption is context-specific and is difficult to generalize. In addition, it is evident that farmer and farm variables tend to influence each other and thus influence decision making.

Some common overall patterns in adoption behaviour do exist, however they are not without some contradictions. For example, small farm owners tend to be more concerned about the environment in comparison to farmers owning large farms (Filson, 1993). However, farmers with successors for their farms were concerned about the environment despite the size of their farms (Traoré, Landry, & Amara, 1998). Overall, due to the context-dependent nature of farmer decision making there is a need to conduct local site-specific studies.

CHAPTER 3: METHODS

3.1 Rationale

The main objective of this study is to understand the relationship between farmers and water resources. To investigate this relationship I used elicitation interviews to capture farmer perceptions of ecosystem services, climate change, and water quality, and how these perceptions influence farmer decision making. Farmer perceptions are context dependent, and each farm has a different set of water bodies and unique water management challenges. This demands a versatile data collection method that is sensitive to context. In this study, semi-structured interviews were used since they provide room for flexibility and allow the researcher to focus on specific aspects that are relevant and important to the participant (Barriball & While, 1994; Dicicco-Bloom & Crabtree, 2006). Semi-structured interviews are appropriate when personal and sensitive topics are discussed (Leech, 2002). They allow the researchers to engage in a conversation with the participants, and assure them there is no need to answer questions that cause discomfort (Leech, 2002). In this study, we used maps as a visual elicitation tool during semi-structured interviews to prompt discussions related to different water bodies, the watershed, and the place of the farm within it. Maps are visual prompts that are useful in jogging farmers' memories of different water bodies and capturing information that cannot be obtained easily through verbal interviews alone. In the following sections, the methods used in data collection and data analysis are discussed. All the data collection methods used in this thesis were approved by the Research Ethics Board at Dalhousie University.

3.2 Sample & Recruitment

The study region, the Musquodoboit Valley Watershed, is located in the North-Eastern region of Halifax Regional Municipality (Figure 1). The watershed spans a total area of 1409 Km^2 and is characterized by the flow of the Musquodoboit River. The river drains into Musquodoboit Harbour after passing through a series of coastal wetlands; these wetlands have been designated as internationally important by the RAMSAR convention (1987) (Province of Nova Scotia, 2001)., Resource based industries such as forestry and agriculture are common livelihoods for residents within the Musquodoboit

Watershed. About 70% of the land within the watershed is used for forestry purposes and 10% exists as agricultural land and the remaining 20% is designated for commercial or residential development (Stea, 2013). Despite the small agricultural area within the watershed, farms are often located in close vicinity to major waterways including the Musquodoboit River and can have a major impact on water quality. Farming activities in the Musquodoboit Valley include dairy, beef livestock operations, forage crops and blueberry production (P. Brenton, personal communication, 2013). Farmers were eligible to participate in the study if they farmed land within the Musquodoboit watershed and earned their primary income through agriculture (thus excluding hobby farmers). It has been observed that the number of farms and farmers in the region has been declining over the years. However, agriculture continues to play an important role in the region's economy, landscape, and culture. Key informants estimate that there are only about 15 to 20 active farmers within the watershed (Paul Brenton, Nova Scotia Federation of Agriculture, personal communication).

Participants were initially identified through snowball sampling. Snowball sampling involves asking a few key members of the community to identify individuals who qualify for the study (Handcock & Gile, 2011). Snowball sampling was used for this study, because there is very little publicly available information on farmers and thus the information provided by insiders is valuable for recruitment. Key informants working in different sectors in the area were contacted. Key informants included the Provincial Regional Agriculture Coordinator, and staff from Federal Department of Agriculture, Ducks Unlimited Canada, Halifax Water, as well as vendors from the Musquodoboit Harbour farmers' market. Through referrals from key informants, the first set of participants was chosen. Key informants were notified that the farmers will be contacted to participate in this study and their referral will be mentioned. Farmers were initially contacted through phone calls to invite them to participate in the study.

When farmers agreed to participate in the study, a letter was sent with detailed information about the interview process (Appendix 1). Property Identification Number (PIDs) of all their land parcels were requested from the participants to create farm maps. Some farmers had multiple pieces of agricultural land and were not able to recall their

PIDs over the phone. To overcome this obstacle, the Provincial Property Online database was used to identify PIDs of participants using land owner's name, address and phone number. After their interview, participants were requested to identify other farmers in the region who might be willing and eligible to participate in the study. More participants were identified through referrals from the first set of participants. In addition, the study was advertised through the Dairy Farmers of Nova Scotia monthly newsletter (Dairy Farmers of Nova Scotia, 2013). Participants were also identified through the Select Nova Scotia website and through the Musquodoboit Valley local food directory. A total of 15 farmers were identified and contacted. Ten participants expressed interest in participating in the study and were interviewed. This small sample size is mostly due to the limited number of farmers in the region and logistical issues such as scheduling interviews. Most farmers in the region had busy schedules in the summer months and also had businesses outside of farming, making it difficult to schedule interviews. However, the participants in this study farmed a total of 498 ha within the watershed on farms spread throughout the watershed (Upper Musquodoboit, Middle Musquodoboit and Elderbank regions). Although relatively small in number, we believe farmers who took part in this study play key roles within this watershed and their farm water management activities have the capacity to affect water quality and quantity of the Musquodoboit River.

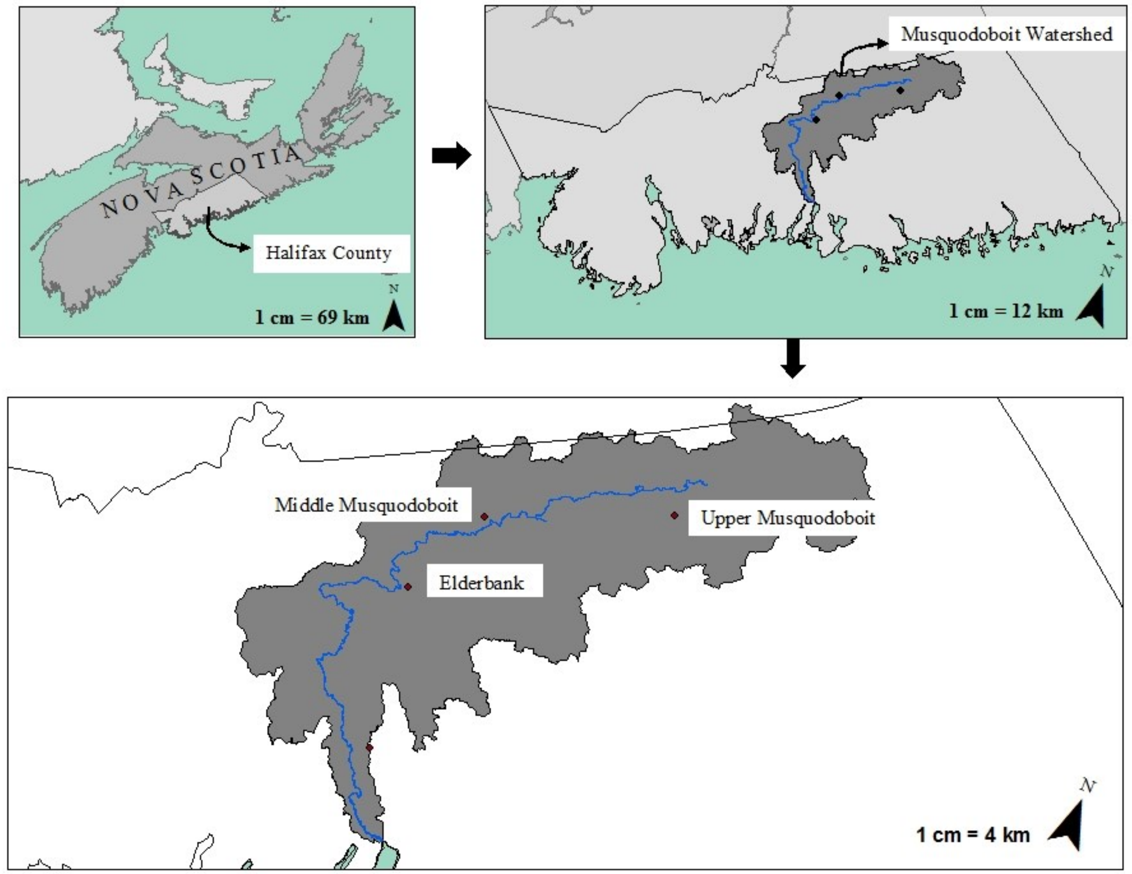

Figure 1: Location of the study area, the Musquodoboit Watershed in Halifax Regional Municipality, Nova Scotia.

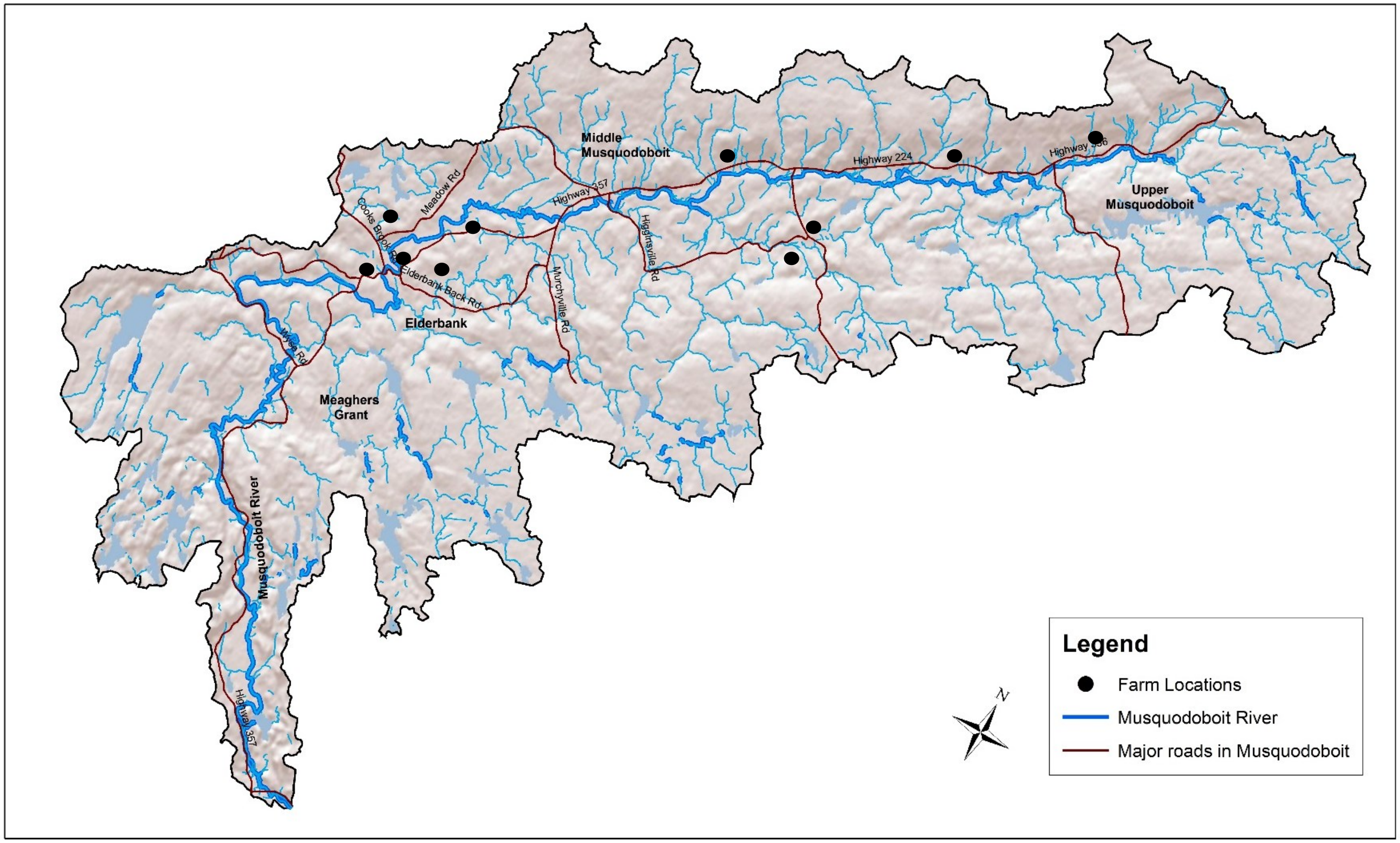

Figure 2: Map of the Musquodoboit watershed used for elicitation purposes. This map includes data from the Primary Watersheds of Nova Scotia and the Topographic Database of Nova Scotia (Refer to table 1 for sources). Approximate location of the farms that were part of the study are also included in the map.

Figure 3: Farm map with aerial photography used for elicitation purposes. This map includes an aerial photograph base map from ESRI (2006) and data on property boundaries and wetlands (Refer to Table 1 for sources)

3.3. Map-based elicitation

Several visual objects, such as drawings (Barraza, 1999), photographs (e.g. Atwell, Schulte, & Westphal, 2009; Sherren & Verstraten, 2012) and art (Bagnoli, 2009) have been used as elicitation tools by researchers to understand the relationships between humans and the natural environment. The goal of an elicitation tool is to aid in knowledge acquisition from participants (Bagnoli, 2009). The use of an elicitation tool is particularly useful when the subject matter under consideration would benefit from an external stimuli other than verbal questioning (Crilly, Blackwell, & Clarkson, 2006). Even though maps have been traditionally used to represent the physical landscape in an objective manner (Fahy & Cinnéide, 2009), they are increasingly used as a participatory tool (Rambaldi, Corbett, & Olson, 2006). For example, maps have been used to include local people in planning and decision making (Fahy & Cinnéide, 2009; Skinner & Masuda, 2013; Vajjhala, 2005). Maps could also be used as an object to understand human perceptions of the landscape (Soini, 2001). In this study, we used maps as a visual stimuli to gain insights from participants regarding waterbodies and the services and disservices they provide. This method was used to encourage a farmer-led discussion based on visual prompts from the maps and with very little input from the researcher. To encourage discussion on issues surrounding water management at different spatial scales both farm and watershed-scale maps was created (Figure 2 and 3).

3.3.1 Watershed scale water management activities

Several environmental management and planning decisions are made at the watershed scale (Bacic, Rossiter, & Bregt, 2006). However, it is not always clear if farmers are aware of the relationship between their farming practices and impacts on water bodies within the watershed (Macgregor & Warren, 2006). To better understand farmers' perceptions of water quality issues within the watershed and shed light on farmers' awareness regarding the impacts of their management practices on waterbodies, a map of the Musquodoboit Watershed (Figure 2) was used in the elicitation process. The farmer was presented with a map of the Musquodoboit Watershed, and was asked to identify their property within the map. Following this identification, questions and prompts were used to start a conversation on the position and role of their farm within the watershed.

3.3.2 Farm scale water management activities

Farmers were also presented with a map of their farm (Figure 3) to aid discussion on farm scale water management. Farmers were asked to identify different water bodies and the areas that pose water management challenges on their farm. This initial identification introduced a discussion about different management practices adopted by farmers. Participants described a variety of water bodies such as ponds, wetlands, wells, and aquifers located within the farm as well as off-farm within the watershed. I expected that the visual stimulus of the maps would elicit emotions and values associated with different locations and provide a rich depth of information (Evans & Jones, 2011; Jones, Bunce, Evans, Gibbs, & Hein, 2008).

3.4 Map Creation

Maps were created using ArcGIS 10.1 (ESRI) and were designed to highlight relevant features such as roads, rivers, streams and other water bodies. The maps were created to:

1) Assist in the identification of water bodies within the farm and in the watershed;

2) Stimulate discussion on the flow of water within the farm and in the watershed; and,
3) Act as a visual prompt that would reduce the number of questions needed.

The watershed map was created using information on the Primary watersheds of Nova Scotia (Nova Scotia Environment, 2011). In addition, major waterway and roadway layers were added to the map (Table 1). The farm scale map identified the property boundaries of the participant's farm using the provided PIDs. In addition, the farm map included aerial photographs as a base layer. Aerial photographs stimulate discussion and are comprehensible to a variety of people despite their educational background (Mather, 2000).

Table 1: The different data sources that contributed to map creation

Map Layers	Source
Topographic Database of Nova Scotia Layers included - Major roads and waterways	Nova Scotia Geomatics Center, April 2012
Primary watersheds of Nova Scotia	Nova Scotia Environment, 2011
Aerial Photograph base map	ESRI, 2006
Wetlands of Nova Scotia	Nova Scotia Department of Natural Resources, 2004

3.5 Semi-Structured Interviews

The key characteristic of semi-structured interviews is that they are open-ended and flexible (Horton, Macve & Struyven, 2004). Typically, the interviewer prepares a series of interview questions, but can vary the structure and sequence of the questions as needed (Barriball & While, 1994). More importantly, the questions are general in their frame of reference in comparison to structured interviews, permitting flexibility (Horton, Macve & Struyven, 2004). This flexibility was the reason semi-structured interviews were chosen for this study. Given that this research was looking at some novel and varied issues, it is difficult to design structured questions. Therefore, the questions and prompts were modified in response to the answers received to the initial questions and the map elicitation process. In addition, semi-structured interviews allow the interviewer to clarify questions, and the participants to clarify their responses and discuss issues that are particularly important to them (Horton, Macve & Struyven, 2004).

I created the interview guide (Appendix I) by discussing the research questions with my graduate supervisor, Dr. Kate Sherren, and a committee member, Dr. Marney Isaac. The interview guide had three major sections. The first section focused on watershed scale processes, and included questions on the position of the farm within the watershed and drainage patterns. Sample questions include:

- What areas have an impact on water within your property? Can you describe the impacts to me?
- Does your farm have an impact on water elsewhere within this region?

The second section focused on farm-level water issues. As part of this section, farmers were asked to identify the costs and benefits of the water bodies that influence their farming practices. The terms, 'ecosystem services' and 'ecosystem disservices' were not used as part of the interview. Many Canadian farmers are unfamiliar with the term 'ecosystem goods and services' and farmers frequently misinterpret the term to mean farm management that benefits the environment (Environics Research Group, 2006). In addition, people relate better to the benefits that arise from ecosystem services than the ecosystem service itself (Sagie, Morris, Rofè, Orenstein, & Groner, 2013). Therefore, the terms 'benefits' and 'costs' were used to represent services and disservices. The questions were not identical for all participants and varied based on the type of water bodies present at the farm, however, the questions were drawn from the interview guide. Sample questions include:

- What are some of the prominent water bodies within your farm?
- Do these waterbodies provide any benefits to your farming activities?
- Do these water bodies provide any costs to your farming activities?

The third and final section of the interview guide aimed to gather farmer understanding of community-level water quality issues and general insights on the future of farming in the region.

- Are you concerned about water quality issues in your community (watershed)?
- What regulations apply to water management and your farming practices? How do you feel about them?

Interviews were conducted at the farm property and lasted between 18 to 210 minutes. The average length of an interview was 38 minutes. Interviews were audio recorded with consent from participants and later transcribed. The content of the maps were not analyzed, however, I used the maps to record areas identified by the farmer, such as water bodies and commonly flooded fields.

3.6 Data Analysis

Following transcription, I used the qualitative software NVivo10 for qualitative content analysis (Elo and Kyngas 2008). A deductive coding approach was primarily used. Following multiple rounds of deductive coding, an inductive coding approach was used to capture other relevant patterns in the data. In preparation for content analysis, I read the transcribed interviews multiple times to become familiar with the data. Sentences were used as a unit of analysis and latent content was not coded, since the research questions can be sufficiently answered with manifest coding. Manifest coding involves analyzing textual content and meaning (Hsieh & Shannon, 2005); while latent coding involves recognizing hidden meanings including silence, sighs, laughter etc (Elo & Kyngäs, 2008)

Data analysis started with attribute coding (Identification of farm size, years of farming experience, relevant water bodies, commodities produced, water quality testing frequency, etc.). A series of deductive codes were created for this study, including: 1) ecosystem service categories (based on the Ecosystem Services framework (MA, 2005)); 2) ecosystem disservice categories (based on Zhang et al. 2007); and, 3) common management practices used by farmers for water management (developed from various literature sources, primarily agricultural handbooks). In addition to these pre-determined codes several disservices and management practices particularly relevant to this location were identified inductively. For instance, the disservices of 'wet areas' was a prominent concern for farmers in the region and was identified inductively.

The first round of coding focused on identifying water related ecosystem services. The costs and benefits identified by farmers were grouped under different ecosystem service/disservice categories (Figure 4). The second round of coding focused on identifying management practices used by farmers to exploit or manage the ecosystem services and disservices arising from water bodies. In addition, each farmer's rationale for using these management practices was inductively identified. The third round of coding was inductive in nature and focused on identifying farmer perceptions of water quality issues and their awareness of the impact of agriculture on water quality. The final round of inductive coding was focused on understanding farmer perceptions of climate change. Interestingly, the interview guide did not include prompts or questions regarding climate change. However, several farmers discussed climate change when talking about the future of farm water management in the region. Subsequently we sought to examine this more systematically, especially in light of indications that climate change was not important for Nova Scotia farmers in 2011 (Sherren & Verstraten, 2012).

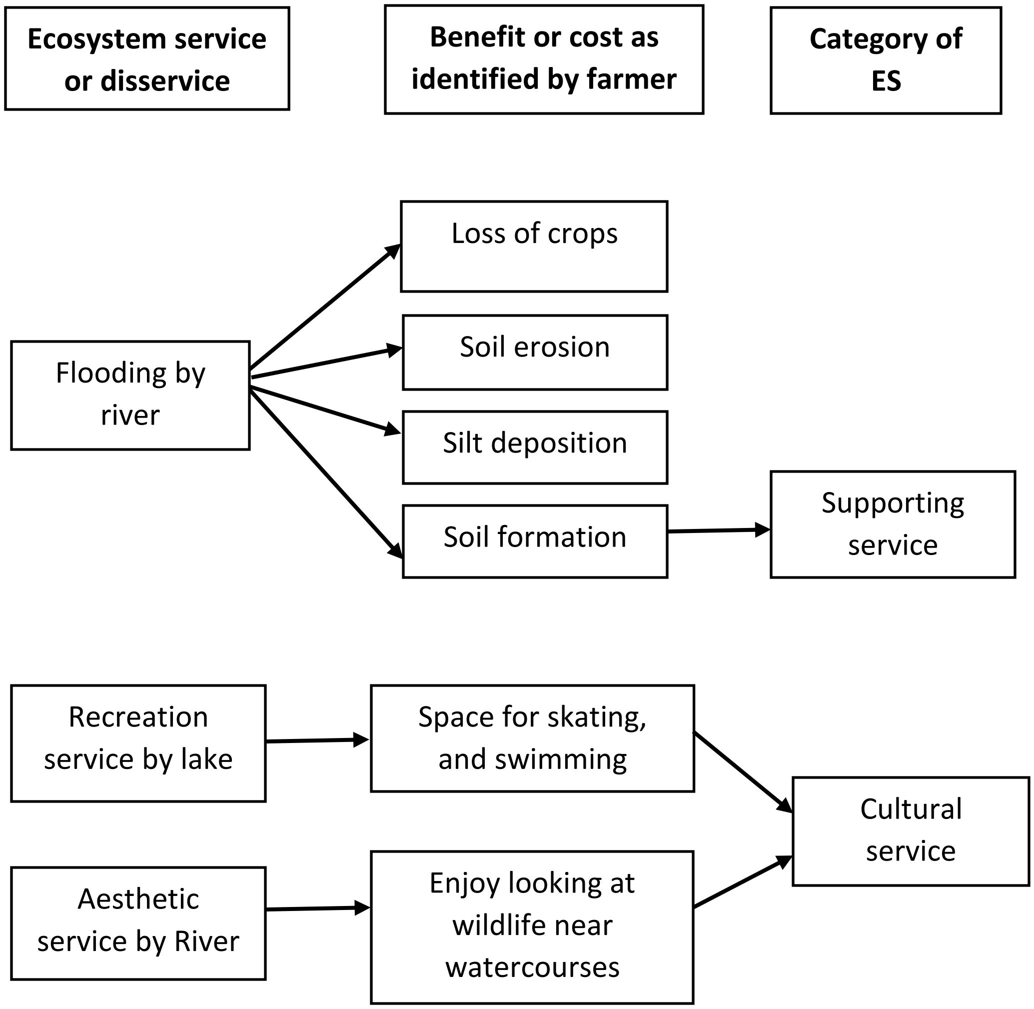

Figure 4: Illustration of the categorization of costs and benefits into ecosystem services and disservices

3.7 Limitations

This study has several limitations. Firstly, the data collection period was limited to June to September 2013, due to time limitations of the researcher. Farmers are particularly busy during this season, and this time frame possibly limited participation. Even though it is estimated that there are only a few (15 – 20) farmers in the region, the study's small sample size makes generalizations difficult. Secondly, the interviews identified multiple management practices, however did not collect information on specifics of each practice. For example, the interviews identified if farmers maintained riparian buffer zones, however, the interviews did not verify the size and location of riparian buffer zones on the farm. Moreover, this thesis is solely based on information gained through interviews, there was no ground-truthing to verify that the different management practices described by farmers in the interviews were actually implemented as described.

Typically qualitative research employing semi-structured interviews use methods such as inter-coder reliability checks to eliminate subjectivity. In this study, I embraced subjectivity and context and discuss my rationale below. Quantitative research uses criteria such as reliability, validity and generalizability to ensure objective measurements. By contrast, Auerbach and Silverstein (2003, p. 77) argue subjectivity, interpretation and context are often defining elements of qualitative research. These authors suggest the use of justifiability of interpretation as an alternative to reliability and validity. The goal is to distinguish between justified and unjustified application of subjectivity to interpret data. Auerbach and Silverstein (2003, p. 83) use transparency, communicability and coherence to attain this goal. In order to justify a researcher's interpretation of data, the data analysis process has to be transparent. This means other researchers need to know the steps used by the researcher for data analysis. Communicable means the data analysis steps, the themes and codes identified by the researchers should be understood by other researchers. And finally, the data analysis should be coherent. The theoretical constructs developed/used by the researcher should help the organization of data and tell a coherent story. Communication of data analysis in this thesis follows guidelines presented by Auerbach and Silverstein (2003), and it is anticipated that this will allow other researchers to understand and evaluate data analysis performed as part of this thesis.

Figure 5: Deductive codes used for data analysis

Ecosystem Service Categories
• Provisioning services ➢ Food ➢ Freshwater ➢ Wood and fibre ➢ Fuel • Regulating services ➢ Climate regulation ➢ Flood regulation ➢ Disease regulation ➢ Water purification • Cultural services ➢ Aesthetic ➢ Spiritual ➢ Educational ➢ Recreational • Supporting ➢ Nutrient cycling ➢ Soil formation ➢ Primary production
Ecosystem Disservice categories
• Soil erosion • Competition for pollination • Competition for water from other ecosystems • Pest damage • Flooding
Management Practices categories
• Cover crops • Preventing livestock access to water source • Land abandonment • Seasonal avoidance • Delay seeding • Tile drainage • Keeping wetland intact • Wetland creation • Riparian buffer • Shoreline armouring

CHAPTER 4: DO FARMER PERCEPTIONS OF ECOSYSTEM SERVICES AND DISSERVICES INFLUENCE THEIR WATER MANAGEMENT?

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Statement of Student Contribution

This chapter is planned as a manuscript to the journal Ecosystem Services. Aiswarya Baskaran was responsible for the research and writing of this manuscript. Dr. Kate Sherren was the thesis supervisor providing guidance and feedback. In addition, committee members, Dr. Marney Isaac and Dr. John Brazner provided revisions and feedback.

4.1 Abstract

Agricultural systems depend on a variety of ecosystem services and in turn generate provisioning services, such as food and fuel, and disservices, such as water pollution from nutrient run-off. Regulating services, such as water flow regulation and water purification by wetlands, are particularly important to mitigate agricultural pollution. To protect water resources from agricultural pollution, it is important to understand existing farm water management practices and factors that influence farmer decision making. The main objective of our study is to illustrate and analyze farmers' perceptions of water-related ecosystem services, and the influence of such perceptions on farm water management. In addition, we also explored farmers' perceptions of climate change and how that influences farmer decision making. We conducted 10 semi-structured interviews, and used maps to elicit farmer perceptions, in the Musquodoboit watershed in the Atlantic Canadian province of Nova Scotia. Our results indicate that farmers easily identify provisioning and cultural services originating from water bodies; however, those same farmers have limited awareness of regulating and supporting services. Farmers had observed an increase in disservices such as flooding and wet areas, possibly due to a decline in regulating services. Farmers' perceptions of ecosystem services and disservices influenced their decision making. For instance, farmers protected water bodies that provide them provisioning and cultural services, and wetlands that performed water purification. Decision making was also influenced by their production goals and the nature of the management practice under consideration. Implications for agri-environmental programs are discussed.

4.2 Key Words: Ecosystem services, map-based elicitation, farmer perceptions, farmer decision making and water management.

4.3 Introduction

Agricultural production depends on a variety of ecosystem services, such as provisioning (water for irrigation) and supporting services (soil formation) (Power, 2010). Regulating services are particularly important to agriculture because they: provide direct benefits including clean air and water; influence the capacity of an ecosystem to provide other ecosystem services; and, provide ecological resilience (Sutherland & Gardner, 2011; Villamagna et al., 2013). Water regulation, erosion control, biological control, and pollination are some intermediate regulating services used by agriculture for food production (Zhang, Ricketts, Kremen, Carney, & Swinton, 2007). However, the contribution of regulating services is often under-recognized and under-appreciated (Kumar & Wood, 2010). This primarily stems from the difficulty in understanding the complex and large scale ecosystem processes that generate regulating services (Villamagna et al., 2013). Intensive agricultural practices are known to increase the delivery of provisioning services and subsequently negatively affect the capacity of an ecosystem to provide regulating services (Power, 2010; Rodríguez & Beard, 2006).

Among the regulating services identified by the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment, 2005), services that contribute to the maintenance of water quantity and quality, mainly water regulation and water purification, are particularly important to agriculture. Agriculture is the largest consumer of water resources (70% of global freshwater withdrawals are used for irrigation), and it is also an important source of diffuse (non-point source) pollution (Carpenter, Stanley, & Vander Zanden, 2011; Schwarzenbach, Egli, Hofstetter, von Gunten, & Wehrli, 2010). Farmers make water and soil management decisions on their farms that affect the quantity, quality and timing of water flow downstream. The diffuse nature of non-point source pollution and the social and economic challenges associated with farm-by-farm enforcement, makes it very difficult to impose regulations on agricultural water management (Moss, 2008). Given the important role that farmers play in water management, to manage agricultural pollution it is crucial to understand farmer behaviour and decision making. This understanding will allow us to create better regional agri-environmental programs that encourage positive behaviour change among farmers.

Farmer behaviour and decision making can be affected by extrinsic factors such as legal requirements and economic incentives or by intrinsic socio-cultural factors that encourage voluntary action (Blackstock, Ingram, Burton, Brown, & Slee, 2010). Previous studies found that farmers' decisions surrounding farm management were largely influenced by their values, knowledge and experience (e.g., Eckert and Bell 2005). Knowledge and experiences are likely shaped by farmers' perceptions of the environment and will likely influence decision making (Vignola, Koellner, Scholz, & McDaniels, 2010). Past studies have documented farmers' beliefs, values and perceptions of the environment in general (Amsalu & Graaff, 2006; Atkins & Eastin, 2012; Riley, 2009). In recent years, the concept of ecosystem services is increasingly being used to make natural resource management decisions. However, very few studies have documented farmers' perceptions of specific ecosystem services and how those influence decision making (Guillem & Barnes, 2013; Orenstein & Groner, 2014; Poppenborg & Koellner, 2013). Even though farmers are regarded as important users and stewards of ecosystem services, there is limited understanding of farmers' perceptions of ecosystem services (Sandhu, Wratten, & Cullen, 2007) and the management practices farmers use to control the delivery of ecosystem services.

The ecosystem services framework has been used widely to assess and catalogue ecosystem services (Costanza & Kubiszewski, 2012). However, most researchers have focused only on biophysical and economic approaches to understanding ecosystem services. There is limited research on social evaluations and stakeholder perceptions of ecosystem services (Orenstein & Groner, 2014). It is important to understand stakeholder perceptions to support decision making surrounding natural resource management. More recently, researchers have begun to explore stakeholder perceptions of ecosystem services at the national level (Martín-López et al., 2012; Orenstein & Groner, 2014), in peri-urban ecosystems (rural-urban fringe) (Casado-Arzuaga, Madariaga, & Onaindia, 2013), in agricultural ecosystems (Smith & Sullivan, 2014; Vignola et al., 2010), and even in oceanic island nations (Butler et al., 2014). These studies aimed at understanding how different stakeholders value and manage ecosystem services. Perceptions depend on the site and beneficiary (Boyd & Banzhaf, 2007) under consideration. There is very little understanding of farmer perceptions and attitudes towards ecosystem services in Canada. In addition, the concept of ecosystem services is commonly misunderstood by Canadian farmers (Environics Research Group, 2006).

We are particularly interested in the ecosystem services and disservices that arise from water bodies. Water resources are of particular interest because it is expected that water and agricultural management will become increasingly challenging under climate change. This study is situated in Atlantic Canada, and it is predicted that climate change will bring extreme weather and variable precipitation to Atlantic Canada, and presents an uncertain future for water resources and water-dependent sectors such as agriculture (Bootsma, Gameda, & Mckenney, 2005; Lines, Pancura, Lander, & Titus, 2008). Changes to farming practices are necessary to adapt agriculture to climate change (Fleming & Vanclay, 2010). Adaptive capacity is defined as the ability of individuals and societies to change their behaviour in response to changing circumstances (Fazey, Fazey, Fischer, Sherren, Warren, Noss, & Dovers, 2007). Understanding existing management practices and the reasons for adopting these practices can serve as a starting point to understand farmers' adaptive capacity. Regulating services provide ecological resilience to farmland ecosystems when faced with disturbances such as variability induced by climate change (Carpenter, Bennett, & Peterson, 2006); therefore, it is particularly important to understand the management of ecosystem services in the light of climate change.

The main objective of this study is to understand how farmers perceive water-related ecosystem services, and the role this perception plays in influencing farmer decision making on farm water management. In addition, this study also explores how farmers' perceive climate change, and how climate change perceptions could influence decision making on water management. In exploring farmers' perceptions of climate change we hope to gain insights into the different management practices farmers might use to adapt to climatic variability.

4.4 Methodology

4.4.1 Study Area

The Musquodoboit watershed is located within Halifax Regional Municipality in Nova Scotia, one of the Maritime provinces on Canada's east coast, and covers a total area of 1409 km^2 (Figure 1). The Musquodoboit River drains into the Atlantic Ocean after passing through a RAMSAR site consisting of coastal wetland complexes (Province of Nova Scotia, 2001). With an approximate population of 30,000, rural communities within this watershed engage in forestry and agricultural activities (Nova Scotia Community Counts, 2014; Halifax Regional Municipality, 2010). This particular watershed was chosen because Halifax Water, the local water utility, and The Nature Conservancy of Canada, are interested in source water protection within this watershed. 70% of the watershed is used for forestry activities, 10% is used for agricultural operations and 20% is designated for commercial and residential development. These organizations typically protect source water and critical ecosystems through land acquisition; however, in this case they are aware that farmer outreach may be a necessary alternative. (B. Geddes and C. Smith, personal communication, November 2012). The Musquodoboit River provides source water for the town of Middle Musquodoboit and serves 96 households, and also serves as important habitat for the endangered Nova Scotia Southern Upland Atlantic salmon population (COSEWIC, 2011; Gibson, Bowlby, Hardie, & O'Reilly, 2011). The river experiences high *Escherichia coli* concentrations (Stea, 2013) and high nitrate levels following heavy rainfall events (B. Geddes, personal communication November 2012).

4.4.2 Data Collection

Qualitative data collection methods, semi-structured interviews and map elicitation were used. Farmers located within the Musquodoboit watershed were identified using the snowball sampling technique (Heckathorn, 2011). Participants were initially identified through referral from key informants (individuals working with farmers in the region, such as agricultural co-ordinators, government staff and farmers' market vendors). Participants were engaged in mixed commodity production (Table 2), commonly forage/silage (7), beef (4), grain (4), dairy (3), and vegetable/corn (3). Typical commodities for agriculture in the Halifax region in Nova Scotia, Canada include corn and floriculture production (Statistics Canada Census of Agriculture, 2006). We interviewed ten farmers as part of this study. Given the small number of active farmers in the region (estimated to be 15-20), ten participants is sufficient for qualitative analysis. Moreover, the participants together own 498 ha of primary farm land within the watershed (Table 2), and in most cases in proximity to the Musquodoboit River, making them key stakeholders of the farming community in the watershed. Individually however, they own smaller farms than the Nova Scotia average of 105.5 ha (Nova Scotia Department of Agriculture, 2011)

All participants were male except for one female farmer, and all farms were family owned and operated. In addition, each participant had at least 30 years of experience farming in the region (Table 2). The average age of farmers in the Halifax region is 53.1 years (Statistics Canada Census of Agriculture, 2006); all participants except one were in a similar age group (personal communication during interviews). To aid the interview process, farmers were presented with a map of their farm (Figure 2) and a map of the watershed (Figure 3). Maps were created using ArcGIS10.1. Using the maps as prompts, we asked the farmers to spatially identify water bodies within their farm and in the vicinity of their farm. A semi-structured interview followed this identification, discussing the benefits and costs associated with each water body and the farmer's choice of management practices as a result. We refrained from using the term "ecosystem services" since in the past Canadian farmers have misunderstood the term as denoting the services that benefit the environment rather than individuals (Environics Research Group, 2006). The average length of an interview was 38 minutes. Interviews were audio recorded and transcribed.

Table 2: General characteristics of the farmer and their primary farm

Farmer	No. of years farming in the region	Property size of primary farm (ha)	Farm Type
1	31	67.6	Forage and beef
2	34	66.4	Grain & blueberry
3	43	59.5	Forage and beef
4	51	56.7	Grain, silage and beef
5	30	42.5	Corn, forage and dairy
6	40	44.5	Forage and beef
7	32	36	Forage and dairy
8	36	93	Forage and dairy
9	32	18.6	Grain and vegetables
10	35	13.1	Grain and vegetables

4.4.3 Analytical Framework.

In this study, we adapted the Millennium Ecosystem Assessment (MA) conceptual framework of ecosystem services (Millennium Ecosystem Assessment, 2005). We chose this framework because it has previously been used to understand farmers' perceptions and knowledge of ecosystem services (example, see Sandhu, Wratten, & Cullen, 2010; Sandhu et al., 2007; Smith& Sullivan, 2014; Silvano, Udvardy, Ceroni, & Farley, 2005), and as a participatory tool to engage stakeholders (Folke et al., 2005). The MA framework categorizes ecosystem services into provisioning, regulating, cultural and supporting services. Provisioning services are the products humans obtain from ecosystems (e.g., food, freshwater and fuel). Regulating services are the benefits human obtain from the regulation of ecosystems. Cultural services include the non-material benefits obtained from ecosystems, through various spiritual, recreational and aesthetic experiences. The MA framework defines supporting services as the services that are necessary for the production of all other services (e.g., soil formation and nutrient cycling). In addition to the benefits, humans also incur costs (financial or otherwise) from ecosystem processes (Lyytimäki & Sipilä, 2009). Common disservices such as flooding and pests can influence farmer decision making on ecosystem service management (Zhang et al., 2007).

4.4.4 Data Analysis

Interviews were transcribed and analyzed using qualitative software NVivo10. We did not analyze the maps; however, we used them to identify the different water bodies discussed by the farmer and the presence of riparian buffers. We used a deductive approach to identify farmer perceptions of water-related ecosystem services, and the different management practices farmers used. In addition, we used inductive content analysis to capture farmer perceptions of climate change. We created a list of deductive codes for services and disservices using the ecosystem services framework (MA, 2005) and the list provided by Zhang et al. (2007). In addition, a list of deductive codes for different management practices used by farmers was derived from agricultural extension literature sources relevant to Nova Scotia (Miller, Peterson, Lenhart, & Nomura, 2012; Nova Scotia Federation of Agriculture). The first round of deductive coding involved identifying different water bodies, and the benefits and costs farmers associate with the water bodies and assigning them to respective ecosystem service or disservice categories. The next round of deductive coding identified management practices used by farmers to leverage services or manage disservices. Additionally, inductive codes were created when farmers stated their rationale for carrying out different management practices and/or discussed their perceptions of climate change.

4.5 Results

We discuss farmer perceptions of ecosystem services using the ecosystem service categories from the MA framework. Regulating and supporting services are under the same subheading since there are few instances where farmers discussed these services. In addition, farmer perceptions of disservices and climate change are presented. We use quotes from the interviews to illustrate some of the key issues discussed by farmers.

4.5.1 Farmer perceptions of ecosystem services.

Farmers identified various water bodies, including on-farm man-made water bodies, such as wells and farm ponds, and off-farm water bodies, such as rivers, brooks and lakes. Farmers attributed different services to these water bodies (Table 3).

Provisioning services

The most widely recognized service was freshwater provision (Table 3) for domestic use, irrigation and livestock. All participants had positive perceptions regarding water availability and felt there was plentiful water available for their agricultural operations. Two farmers encountered dry spells in the summer, however, not enough to affect irrigation activities. Wells and farm ponds were the major freshwater sources mentioned. In addition, some farmers (4/10) discussed the connectivity between their on-farm water source and underground water sources, such as aquifers and underground springs. Despite the close proximity of the farms to the Musquodoboit River and its tributaries, none of the farmers pumped water out of these waterways. All participants felt that the option of using the Musquodoboit River for future water supply should be kept open. Farmers expressed this option value by discussing future scenarios:

> We have the River running through our property. We have, thus gives us the opportunity or availability of water in drought conditions. If we had a specific crop at that particular time, that was drought stricken and that needed to be saved. Then we would....we would if nothing else, we have availability of water – Farmer 8

Cultural services

The second most commonly recognized service was the recreational opportunity provided by water bodies (Table 3). Rivers were used by farmers and their family members for recreational activities such as swimming, canoeing and camping. Farmers also recognized the recreational use of the river by residents and visitors (Table 3). When discussing recreational activities, most farmers (7/10) fondly recalled spending time with their family, especially children. Farmers used storytelling to express their attachment to water bodies:

> There is nothing like it, I love brooks and streams. It is peaceful, serene and beautiful. I grew up along the River, I get why people who live in the city don't love water. They live far away from it. I have lived close to the River, all my life. It is just in that brook right there, there used to be trout populations and we caught them and put them back in. My grandkids live in the city and come down in the

summer and we go fishing. It is the same water, everything is connected and we are all part of it – Farmer 9

The stories told by farmers often indicated that specific water bodies gave them a sense of place. In this context, sense of place is derived from specific physical landscape features and the recreational opportunities these features enable, as described by Stedman (2011). In addition, some farmers (6/10) appreciated landscape features, such as rivers and lakes, that attracted wildlife and considered the presence of wildlife nearby to be an aesthetic service.

Regulating and supporting services

Compared to provisioning and cultural services, regulating and supporting services were less recognized by farmers. The most commonly recognized regulating service was the purification of waste water by wetlands (4/10). Only one participant mentioned the value of contour ditches for regulating the flow of run-off into the river and reducing pollution. Contour ditches are ditches dug along the contour (placed horizontal in a slope) to reduce water from running down the slope and causing erosion. All other participants had vertical ditches to hasten flow. Half of the farmers (5/10) identified the supporting service of soil formation and soil fertility provided by rivers and streams.

Table 3: The ecosystem services identified and the management practices farmers used. Source of the ecosystem service and the number of farmers possessing the source on their farm is also included.

Ecosystem Service		Source	No. of farmers who identified the service/ No. of farmers with the source	Management practice used	No. of farmers using these practices
Provisioning	Freshwater provision	Well	9/9	Water extraction	9
		Farm Pond	6/6	Preventing direct access (fencing and water tubs)	6
		River	10/6*	Not extracting from the river at present	10
Cultural	Recreation	River	9		
		Lake	5		
		Wetland	2/5	Wetland creation	2
	Habitat for wildlife	Wetland	2/5	Wetland creation	2
		River	4		
	Sense of place	River	4		
Regulating	Water regulation	Ditch	1/10	Creation and maintenance of contour ditches	1
	Water purification	Wetland	4/5	Wetland maintenance	4
Supporting	Soil formation & fertile soil	River	5/10	Farming adjacent to the river	3

* In case of the River as a source, six farms were located adjacent to the river and had direct access.

4.5.2 Farmer perceptions of ecosystem disservices

When asked about costs from water bodies, farmers discussed the disservice of flooding and the presence of wet areas. Farmers directly affected by flooding (6/10), experienced the loss of arable land, soil erosion, silt deposition, flooding of cropland, damage to livestock and sometimes threat to human life (Table 4). Some farmers (4/10) were not directly affected by flooding; however, they considered it to be a community level disservice disrupting normalcy. All flooding occurring in the region was attributed to the overflow of the Musquodoboit River and its tributaries. Changes in precipitation and weather (8/10) was the most mentioned contributor to flooding, followed by improper forestry practices (5/10), and improper river maintenance characterised by the absence of river dredging and build of sedimentation in streams and rivers (4/10). Farmers affected by flooding identified the different regions of their farm which were prone to flooding. In addition, farmers felt the magnitude and frequency of flooding has changed over time and it is harder to predict. Farmers noted that while previously a single spring time flooding was common, in recent years both spring and summer flooding had occurred.

All participants identified the loss of arable land due to the presence of wet areas within their farm as an economic cost to their agricultural operations (Table 2). Farmers described wet areas as regions within the farm that are subjected to periodic or consistent wetness; wet areas could possibly refer to wet meadows that were historically drained and filled for agricultural purposes. For the purposes of this study, we distinguish between wet meadows (wet areas) and other wetland types. Underground springs and poor soil drainage characteristics result in wet areas on the farm. Seasonally wet areas reduced the amount of arable land available and in some cases resulted in damage to farm equipment. In addition, seasonally wet areas permitted the growth of undesirable plants in pasture land. A few farmers (2/10) considered the presence of wetlands as a cost since it reduced the amount of arable land.

Table 4: The ecosystem disservices identified and the management practices farmers used. Source of the ecosystem disservice and the number of farmers possessing the source on their farm is also included.

Source	Ecosystem Disservice	No. of farmers who identified the disservice	Management practices used by farmers to manage the disservice	No. of farmers up taking these practices
River Flooding n = 6	Loss of crops	5	Delayed seeding	3
			Land Abandonment	3
	Soil erosion	5	Riparian buffer	5
			Cover crops	5
			Shoreline armoring	1
	Silt deposition	2	Riparian buffer	2
	Damage/threat to livestock	3		
	Threats to human life	2		
Wetland n = 5	Nuisance from wetland birds	3	Managing wetland birds by scaring them	2
	Loss of arable land	2		
	Beaver dams	1	Removal of beaver dams when necessary	1
Wet area n = 10	Loss of arable land	8	Tile drainage	9
			Land abandonment	3
	Damage to farm equipment	2	Seasonal avoidance	2

4.5.3 Management practices

Farmers used a variety of farm management practices to manage the services arising from water bodies (Table 5). Farmer rationales for using each practice varied (Table 3 & 4). It is important to note that these findings are context-specific and should be interpreted with caution, given that the number and types of water bodies present within each farm varied. Farmers (6/6) protected freshwater sources (farm ponds) by using fences and water tubs and thus restricting livestock access. Despite the proximity of the Musquodoboit River and its tributaries, none of the farmers extracted water from these sources. In a few cases, farmers (2/5) created wetlands to provide habitat for wildlife and create recreational space. When the role of ditches in water flow regulation was identified the importance of creating and maintaining contour ditches that slow down the flow of water and reduce soil erosion was also discussed by one farmer (1/10). All of the farmers who recognized the water purification role of wetlands also maintained wetlands within their farms and avoided draining them (4/5). Out of the five farmers who recognized the supporting service of soil formation and fertile soil provided by rivers, three continued to farm adjacent to the river to reap the benefits of fertile soil.

Similarly, farmers used management practices to manage disservices arising from water bodies (Table 4). In cases where farmland was frequently flooded, many farmers chose to abandon the land. When the damage caused by flooding was less severe, farmers seasonally avoided certain fields and delayed seeding to prevent crop loss. Farmers used cover crops and established riparian buffers to reduce soil erosion. An individual farmer even made attempts to reduce soil erosion through shoreline armoring along the river bank. In addition to farm-level practices, farmers suggested the use of engineering interventions such as dredging of the river to control flooding within the watershed. To reduce wet areas, farmers seasonally avoided portions of their farm or installed tile drainage to gain access to arable land.

Table 5: Description of the different management practices used by farmers to manage water resources

Practice	Objective	Description
1. Cover crops	To reduce erosion in lands adjacent to streams and brooks	Crops are planted to provide soil cover and reduce exposure of soil.
2. Fencing and water tubs	To prevent contamination and livestock trampling	Direct access to water is prevented by using fences and containing livestock
3. Land abandonment	To avoid crop loss caused by flooding in land adjacent to the river and brooks	Avoid planting in land that is prone to flooding. Usually, the region is overcome by natural vegetation.
4. Seasonal avoidance	To avoid crop loss caused by flooding in land adjacent to the river and brooks	Seasonally avoid land that is prone to flooding.
5. Delay seeding	To prevent seed rotting caused by flooding and avoid reseeding costs	Delay seeding in regions prone to flooding, thus avoiding reseeding
6. Tile drainage	To drain wet areas and gain access to arable land	Tile drainage along with a series of ditches removes excess water from the soil subsurface region
7. Keeping wetland Intact	To allow water purification function of wetlands	Allowing natural wetlands perform their functions by avoiding wetland draining
8. Wetland creation	To create recreational opportunities and as an alternate use for flood prone land	Creation of new wetlands with assistance from Ducks Unlimited
9. Riparian buffer	To reduce soil erosion and to protect water sources	Riparian buffers are vegetated land strips situated between water bodies and farm land
10. Shoreline armoring	To reduce soil erosion caused by flooding	Rocks are placed along the shore of rivers and brooks
11. Mowing	To eliminate undesirable plants	Undesirable plants in grazing land are removed by periodic mowing
12. Managing wetland birds by scaring them	To remove wetland birds from property and eliminate the threat of water quality degradation	Canada Goose population can degrade water quality through defecation. Farmers used scare tactics such as shooting in the air to remove them from the field.
13. Farming close to River	To gain access to fertile soil and obtain increased crop yields	Farmers planted crops close to the river
14. Livestock crossing	To gain access to pasture fields	Occasionally, livestock crossed across small streams and brooks

4.5.4 Farmer perceptions of the future and climate change

When asked about the future of farming and water management in the region, several farmers (6/10) spoke about succession concerns. A few farmers (4/10) also discussed the economics associated with agriculture. Farmers were concerned that the low profitability and difficulties of farming in this region might deter their children away from farming. In addition, all farmers felt that water management challenges will increase in this watershed in the future.

Most farmers (8/10) spoke elaborately about climate variability and climate change and what it means to water management. Farmers had a high level of climatic awareness, and used terms such as climate change, greenhouse gases, and recalled major weather events from the past and observed climate trends. Farmers denoted that climate had changed during their time in Musquodoboit. Some farmers (6/10) discussed the impact excessive rain had on agriculture:

> I would say there is a lot more water than we would use to deal with and we get into wetter spells than we used to get into. Like I say, I can remember last year September and part of October we must have had 14-15 inches of rain and the year before it was October and November, and we had 19 inches of rain. And, when you get that much of rain in such a short period, you know it is almost half a year's supply. It makes farming difficult, because you start to rut your land. – Farmer 2

In addition, some farmers (6/10) also felt that there is an increased frequency of flooding. Farmers expressed frustration when discussing the unpredictable nature of the weather:

> When I plant a crop in rain, I have no idea what I am gonna get. When I harvest, I have no idea what I am gonna get. You gotta factor in weather. And, the weather we have been having lately hasn't been very co-operative, it is unreliable. So, and all those things make or break it. And, you have no control over the weather, you have no control over the water, and you just gotta go with the flow and try and adapt. – Farmer 8

Interestingly, some farmers (4/10) felt flooding can be controlled by hydrological engineering interventions, such as control dams and levees. However, most farmers (6/10) questioned the efficiency of flood control measures. In addition, these farmers were doubtful of their individual capacity to manage impacts that arise from climate change:

> If the country and the world doesn't find a way to get a better control of the greenhouse gases, then we are all cooked. And, water is a big part of that, water is a huge part of that...and I know that. I know we, I have assumed that little drainage swamp ...we got, that is going to be always there...cleaning all that out for you. But if it dries up or what if everything floods, what happens then? And, what would we do? - Farmer 3

4.6 Discussion

4.6.1 Farmer perceptions of ecosystem services and disservices

Farmers in the Musquodoboit River Valley most commonly recognized provisioning and cultural services from water bodies. Regulating and supporting services were less commonly recognized. Previous studies on ecosystem service perceptions have found that humans first recognize provisioning services, then regulating services, followed by cultural services, and finally supporting services (Agbenyega, Burgess, Cook, & Morris, 2009; Hartter, 2010; Iftekhar & Takama, 2007). In our study, farmers most commonly recognized the service of freshwater provision, which is not surprising given the importance of water to agricultural production. Rodriguez and colleagues (2006) argue that provisioning services are perceived by society as more important because they are tangible and easily identifiable. Cultural ecosystem services are known to aggregate in hotspots particularly surrounding prominent landscape features such as major water bodies (Milcu, Hanspach, Abson, & Fischer, 2013; Plieninger, Dijks, Oteros-Rozas, & Bieling, 2013). In other studies, residents considered water bodies to be the most important ES source for recreation, education, aesthetics, and as heritage sites (Plieninger et al., 2013), so the emphasis on the cultural ecosystem services associated with water bodies in our study was not surprising.

However, regulating services were less commonly recognized by farmers in our study. Based on the national inventory of ecosystem goods and services in Canada, we expected farmers to observe stream flow regulating, water quality regulating and recreational services from wetlands (Statistics Canada, 2013). There are several possible explanations why this did not occur. Firstly, awareness of ecosystem services are known to vary among stakeholders based on different factors, such as location (urban versus rural), source of household income and access to ecosystem services (Martín-López et al., 2012; Orenstein & Groner, 2014). Secondly, regulating services are complex (Villamagna et al., 2013) and are often unrecognized and underappreciated (Kumar & Wood, 2010). Another plausible explanation is that regulating services are generated by multiple ecosystems and it is difficult for participants to attribute them to individual water bodies. For instance, it is difficult to credit individual wetlands with the service of flood abatement, because the service of flood abatement is usually achieved through the combined activity of multiple wetlands across the watershed. Overall, farmers easily identified services that were tangible and directly relevant to them.

Several farmers were substantially concerned about the impact of disservices such as flooding and wet areas on their production activities. Farmers discussed the increase in the frequency of flooding, and the amount of wet area over the years. Farmers attributed flooding to changes in precipitation and weather and deforestation activities upstream. It can be interpreted that farmers made indirect references to the decline in regulating services within the watershed, such as flood protection, while discussing disservices. This finding corroborates Villamagna and colleagues' (2013) idea that regulating services are largely unnoticed until the decline negatively affects the provision of other marketable products, such as food and water.

4.6.2 Do farmer perceptions of ecosystem services and disservices influence decision making?

On-farm management decisions were influenced by farmer perceptions of ecosystem services and disservices. For instance, positive perceptions of freshwater provisioning services resulted in farmers taking steps to protect water sources. Similarly, all farmers who considered fertile soil to be an important service used cover crops and established riparian buffer zones to reduce the disservice of soil erosion. Most farmers who considered water purification by wetlands as an important service maintained wetlands within their farms. However, some farmers in our study had negative perceptions of wet areas and wetlands and none of the farmers recognized the service of flood regulation by wetlands. As a consequence, these farmers considered wetlands to be disservices and in some cases even considered draining wetlands. Farmer decision making was also affected by individual farmers' production goals. For example, some farmers continued to plant in flood prone regions to gain access to fertile soil and obtain high yields. This is similar to earlier studies that found farmer decision making was highly influenced by economic goals (Barnes, Willock, Hall, & Toma, 2009; Poppenborg & Koellner, 2013). However, farmer decision making when faced with hazards such as flooding and uncertainty is not simple. Factors such as farmers' perception of risk and the area liable to flood (Pivot & Martin, 2002) affects farmer decision making.

Farmer decision making was also influenced by the characteristics of the management practice under consideration. All farmers in the study had installed tile drainage; despite the cost, farmers expressed satisfaction about the durability and low-maintenance of tile drainage. To the contrary, all participants resented the idea of fencing along river banks, and the task and cost of cleanup after flooding. Overall, farmers preferred management practices that are cost effective, easy to maintain and produce tangible benefits on the farm.

It is important to consider that ecosystem services can be produced and delivered in the same locality, but often they are produced and delivered in two different locations (Bagstad et al., 2014; Locatelli, Imbach, & Wunder, 2013). Therefore, management practices at one location can have an impact on ecosystem services being utilized at a different locality. For instance, in our study three farmers preferred to cultivate land along river banks to maximize the use of fertile soil. This practice results in the elimination or reduction in the size of riparian buffer zones along the river. This local management practice has implications for both local and more distant habitats. Loss of riparian habitat has local biodiversity implications for species that are resident in these habitats or use them occasionally for forage or cover. The eroded sediments that result from a loss of riparian habitats have more far reaching implications since these sediments can travel long distances while suspended in the river and degrade downstream habitats where they settle.

4.6.3 Trade-off between provisioning and regulating services

The focus on increasing provisioning services has possibly resulted in a decline in regulating services in the Musquodoboit watershed. Even though we do not have direct evidence to support this claim, farmers in our study observed an increase in the frequency and amount of flooding and soil erosion, which suggests a decline in the regulating service of flood regulation and erosion control. Ecosystem service trade-off refers to the reduction in delivery of a particular ecosystem service due to the enhancement of another service through man-made management decisions (Rodríguez & Beard, 2006). Previous research has demonstrated that intensive agriculture increases the amount of provisioning services and reduces the delivery of regulating services (Kumar & Wood, 2010; Raudsepp-Hearne et al., 2010). The decline in regulating services will reduce the ecosystem's capacity to adapt to disturbances (Carpenter et al., 2006) leading to an increase in hazards, such as flooding, soil erosion, and associated water pollution, that can cause a decline in provisioning services. However, some agricultural management practices have the capacity to increase regulating services while maintaining or increasing the delivery of provisioning services. In a comprehensive review, Pretty and colleagues (2006) identified different farm-level practices, such as incorporation of soil-improving legumes as cover crops to improve soil health, integration of mixed crops into crop monocultures for pest control, and collective management of irrigation systems for water efficiency, that reduced ecosystem service trade-offs and increased crop yields.

Certain practices used by farmers in our study have the capacity to improve regulating services. For instance, farmers prone to flooding planted sacrificial cover crops to prevent soil loss and protect fertile soil. Sutherland and Gardner (2011) conducted a systematic expert consultation exercise to identify resource management interventions that can help maintain and enhance regulating services. They found that the use of cover crops and reduced tillage has the capacity to enhance eight out of the nine regulating services identified by the MA. Similarly, maintenance and creation of wetlands can enhance six out of the nine regulating services, including water flow and hazard (flood) regulation (see also, Mitsch & Gosselink, 2000; Tockner & Stanford, 2002). Establishment of riparian buffers can enhance water flow regulation and provide natural hazard regulation by increasing connectivity between rives and floodplain.

Simple practices followed by farmers in the Musquodoboit, such as providing water to livestock in troughs away from water bodies, can also improve regulating services, such as water and erosion regulation. However, not all practices followed by farmers in the Musquodoboit were adaptive and had a positive influence on regulating services. For instance, all farmers in the Musquodoboit used tile drainage to remove excess water from poorly drained land. Artificial tile drainage is a major source of non-point source pollution (Gentry, David, Royer, Mitchell, & Starks, 2007; Kinley, Gordon, Stratton, Patterson, & Hoyle, 2007). In addition, the use of tile drainage for draining wetlands and wet areas, and the use of ditches is also known to contribute to the risk of flooding (Wilkinson, Quinn, & Hewett, 2013). Other practices such as deforestation which were practiced in the Musquodoboit watershed can also improve the likelihood of flooding (Wheater, 2006; Wilkinson et al., 2013). Maladaptive practices that contribute to flooding and a possible decline in regulating services are particularly concerning in the light of climate change.

4.6.4 Farmer perceptions of climate change and decision making

Interestingly farmers attributed the climatic variability they observed to the effects of long term climate change. In addition, when discussing future climatic conditions, farmers anticipated extreme weather and an increased frequency of flooding. These results are different from previous research conducted in Nova Scotia, where farmers discussed climatic variability, however only a few farmers attributed climatic variability to long term climate change (Sherren & Verstraten, 2012). It is likely that farmers within the Musquodoboit watershed are more aware of global scale climate change issues, since they have been regularly affected by flooding and are thus more aware of climatic variability (Whitmarsh, 2008). Perceptions of climate change and risk plays an important role in decision making (Adger et al., 2009) and subsequently the capacity to adapt to climate change. Despite the exploratory nature of this research, these results indicate farmer awareness of climate change, and that farmers are aware of the importance of adaptive capacity when faced with extreme weather events. Some farmers promoted the use of hydrological engineering solutions, such as dam building and river dredging, to manage flooding brought about climate change, while others felt these solutions are costly and ineffective. Interestingly a comprehensive study looking at the effects of floodplain interventions on multiple ecosystem services found river dredging had a reducing effect on several ecosystem services including water flow regulation (Schindler et al., 2014). Some farmers viewed climate change as an unmanageable risk. This has serious implications, since an individual's risk perception and prior experience can influence their willingness to adapt to climate change (Adger et al., 2009). However, our study is limited in scope to understand the adaptive capacity of farmers in the Musquodoboit.

4.6.5 Implications for agri-environmental programs

Organizations that want to improve water quality in this region should work with farmers to identify and promote management practices that can enhance ecosystem services, reduce disservices (cost to the farmer) and improve water quality. Based on our findings we suggest the following recommendations, these are presented in the order of ease of implementation.

Land retirement: In response to flooding, some farmers within this watershed have chosen to abandon their land and others have established riparian buffer zones of varying lengths. Farmers who continue to plant crops close to the river are at continual risk of incurring costs due to crop failure, re-seeding and silt deposition. Given the risks associated with farming in flood prone fields, farmers will be willing to retire land if provided with proper information and/or financial assistance. This approach has been successfully applied elsewhere; for instance, in the United Kingdom, where agricultural flooding is a major concern, farmers are choosing to abandon parts of their field and increase infiltration rates by establishing effective riparian zones (Nicholson, Wilkinson, O'Donnell, & Quinn, 2012). Programs should capitalize on farmers' desire to reduce disservices such as flooding and provide assistance for farmers to retire highly erodible and environmentally sensitive land.

Reducing negative externalities: Soil erosion and nutrient run-off are some of the negative externalities that arise from agricultural activity in the Musquodoboit valley. It is possible that the use of drainage ditches, and exposed soil combined with precipitation contributes to soil erosion in these farms. Sediment and erosion control can be achieved by encouraging farmers to use vegetative buffers along drainage ditches and through hay mulching over exposed soil. Manure and nitrogen fertilizer application combined with precipitation most likely contributed to nutrient run-off in these farms. Designing outreach material to educate farmers on the methodology and timing of fertilizer application has the potential to reduce run-off.

Wetland restoration: Individual wetlands provide several benefits; however, the collective action of wetlands across the watershed has the capacity to reduce the negative impacts of flooding and reduce water pollution. Future studies should identify priority regions suitable for wetland restoration and engage farmers in the discussion. Some farmers in this region are interested in the cultural and the water purification services provided by wetlands. In addition, Musquodoboit farmers have difficulties managing wet areas and flooding. Programs should capitalize on farmers' awareness of ecosystem services, desire to reduce disservices, and climatic awareness, and provide resources (information and financial support) to encourage wetland creation and restoration.

4.7 Conclusion

Failing to recognize the relationship between agricultural practices and ecosystem services associated with on-farm waterbodies can result in serious environmental degradation. Our study attempted to understand farmer perceptions of ecosystem services and disservices, and how farmers manage both. Our results illustrate that farmers' decision making on water management is influenced by their ecosystem service and disservice perceptions, production goals, and management practice characteristics. Farmers were particularly keen on protecting the services that they recognized (provisioning and cultural service) and tackling the disservices they faced (flooding, wet areas and soil erosion). In addition, farmers in this particular watershed showed high awareness of climate change impacts.

It is crucial to understand social and cultural dimensions of ecosystem services and include this understanding in decision making. Our study offers novel insights into the link between stakeholder perceptions of ecosystem services and decision making.

Results from this study have direct implications for the development of agri-environmental programs. Future work should use this understanding to engage farmers in discussions on water quality protection.

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CHAPTER 5 – WHAT DO FARMERS IN THE MUSQUODOBOIT VALLEY THINK ABOUT WATER QUALITY AND AGRICULTURAL WATER POLLUTION?

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Prepared as a report to Halifax Water and The Nature Conservancy of Canada. While this thesis research was not funded by these organizations, meetings with these organizations inspired the topic of this thesis. Aiswarya Baskaran was solely responsible for the research and writing of this report. Dr. Kate Sherren, the graduate supervisor provided primary guidance, revisions and feedback.

5.1. Background and Introduction

The Musquodoboit watershed is located in the North-Eastern region of Halifax Regional Municipality and supports a total of 27,846 residents. The Musquodoboit River drains the watershed and flows into the Atlantic Ocean after passing through a series of coastal RAMSAR (Internationally important) wetlands (Province of Nova Scotia, 2001). In addition, the Musquodoboit River is habitat for Atlantic Salmon and consists of floodplains and wetlands otherwise important for wildlife (Watt, Scott, Zamora, & White, 2000, Nature Conservancy of Canada, 2013). The watershed consists of multiple small villages and the town of Musquodoboit Harbour. Residents engage in agricultural and forestry activities, and/or commute to Halifax Regional Municipality for work. Previous research has identified water quality and quantity issues within the watershed. Halifax Water operates a water plant on the Musquodoboit River that supplies drinking water to 96 households in the village of Middle Musquodoboit. Water quality monitoring has identified the presence of *Escherichia coli* and nitrates in water samples from the Musquodoboit River, particularly after flooding of the Musquodoboit River (Stea, 2013; B. Geddes, personal communication). Organizations working in this region have hypothesized that agricultural activities upstream is a significant contributor to the observed water pollution.

Recent research has explored Musquodoboit farmers' perceptions of water-related ecosystem services and climate change, and the influence of these perceptions on farmer decision making (Chapter 3). It was identified that Musquodoboit farmers are well aware of provisioning and cultural ecosystem services provided by water bodies. However, farmers are less aware of supporting and regulating services, including the service of flood regulation by wetlands. In addition, Musquodoboit farmers are concerned about disservices, such as silt deposition and loss of arable land, brought by flooding of the Musquodoboit River. Farmers currently use adaptive practices such as restricting livestock access to water bodies to protect important water sources. In addition, some farmers use adaptive practices such as the establishment of riparian buffers, cover crops and land abandonment to tackle the disservices associated with flooding. Farmers also use maladaptive practices such as tile drainage, ditches and farming close to the river to gain access to arable and fertile land (Chapter 3). However, we have limited understanding of how Musquodoboit farmers perceive water quality.

Tackling non-point source pollution solely through top-down regulatory methods is difficult and often times ineffective (Blackstock et al., 2010). An alternative approach is the Integrated Water Resource Management (IWRM), a holistic water management style that calls for linking of water issues with land-use planning and stakeholder participation (Global Water Partnership Technical Advisory Committee, 2000; Mitchell, 2005). The rationale behind IWRM is that stakeholder participation will introduce a diversity of perspectives that are normally over-looked and encourage compliance among participating stakeholders in the resulting outcomes. In this particular watershed, Halifax Water and The Nature Conservancy of Canada are interested in engaging with farmers to promote beneficial on farm management practices to protect source water. Typically these organizations acquire land for source water protection; however they are also aware of the importance of agricultural outreach and extension to source water protection.

There are substantial challenges with involving multiple stakeholders to manage watersheds (Leach, 2006). Challenges arise primarily because watersheds span across political boundaries, and consist of residents with a plurality of views on water quality (Barham, 2001). Land use activities occurring in the upstream regions of the watershed can negatively impact water quality downstream. However, due to the large size of a watershed, most individuals are unaware of the consequences of their actions. Furthermore, differences in environmental values and perceptions of water quality can create polarized positions and cause inaction or delay in decision making (Lundmark, 2007). These challenges are further exacerbated by the public's limited awareness of watersheds and water quality issues. The first step in overcoming these challenges and carrying out IWRM is to identify and understand stakeholder perceptions of water quality and their role in it. This research sought to understand farmer perceptions of water quality issues within the Musquodoboit watershed. Previous research has suggested that farmers will be motivated to adopt beneficial water management practices if they perceive there is a problem with water quality, and if they believe their actions can make a difference (Napier & Brown, 1993). Similarly, agricultural extension programs often assume that if landowners understand the effects of their land use practices on water bodies, they will be more willing to change their management practices to reduce impact (Macgregor & Warren, 2006). However, it is unclear if farmers recognize the impacts of their farm water management practices on water resources. In that regard, this report will answer the following research questions:

1) What are farmer perceptions of water quality within the Musquodoboit watershed?
2) How do farmers perceive the impacts of their agricultural practices on water quality?

This research used map-elicitation interviews to explore how farmers perceive water quality and the role of agriculture in contributing to water quality. For detailed methods and further information please consult Chapter 3.

5.2. Methods

Semi-structured interviews with open ended questions were used for data collection. In addition, maps of the watershed and individual farms were used as an elicitation tool. Farmers were identified through referrals from key informants, individuals working in the region and familiar with the agricultural community. A total of ten interviews were conducted with farmers on their property and the average length of an interview was 38 minutes. Commodities produced by participants were beef (5), dairy (3), vegetable (2) and blueberry (1). It is estimated that there are a total of 15 – 20 farmers within the watershed (Paul Brenton, Nova Scotia Federation of Agriculture, personal Communication), therefore the interviews are adequately representative. Farmers were provided with a map of the Musquodoboit watershed, and a map of their farm property (Figure 1 and 2). These maps served as an elicitation tool to spur a farmer-led discussion on the watershed and farm water management. Farmers were asked to identify their farm and important water bodies (that support their farming activities) within the watershed map. Additional questions revolved around water quality issues in the watershed and the role of agriculture in it. Interviews were recorded, transcribed and analysed inductively using NVivo10 qualitative software. For additional methodological details see chapter 3.

5.3. Findings

5.3.1. Perceptions about on-farm water quality

Farmers had positive perceptions of on-farm water quality. Farmers primarily obtained water for household purposes and for livestock from wells and farm ponds. All farmers felt that they had no issues with the taste and color of the drinking water they obtained from on-farm water sources. The frequency of water quality testing varied between farmers. Some farmers tested their water yearly (4/10), while other participants tested their water sporadically, in most cases every 2 or 3 years (6/10). Dairy farmers tested water quality every year as part of the Canadian Milk Quality Program. In addition, dairy farmers expressed that maintaining on-farm water quality is important to their operations, since milk production requires good quality water. While, the majority of the responses from the interviews suggest that farmers did not have major concerns about water quality on the farm, a few farmers were concerned about the potential for nuisance birds to pollute their water supply (2/10) and the potential for storm events to impact water quality (2/10).

5.3.2. Perceptions about off-farm water quality

Farmers had varying opinions about water quality within the watershed. Half of the participants (5/10) felt there are no water quality issues facing residents, while others (5/10) discussed existing challenges and potential threats to water quality. Few farmers (2/10) were aware of the high nitrate count in the Musquodoboit River following manure application. Others discussed flooding of the Musquodoboit River (3/10), the close proximity of some farms to the Musquodoboit River (2/10), and old pipes (1/10) as existing challenges to water quality. Some farmers (4/10) who were concerned about water quality challenges in the watershed mentioned having learned of these challenges through conversations with personnel from Halifax Water and Ducks Unlimited, and other residents.

5.3.3. Perceptions about the impact of agriculture on water quality

Farmers were asked about the impact of their farming practices on water quality. The five farmers who felt there were no water quality issues in the watershed also argued that their agricultural activities did not impact water quality. For instance:

> We don't really have a concern about spoiling water ...because we are beef farmers and beef farmers are environmentally friendly ...because we are growing grass, the grass grows the soil in place and therefore you don't get soil erosion and fertilizer running into the water – Farmer 6

Conversely, the other half of the participants who were aware of water quality issues in the watershed were concerned about the negative impact of agriculture on water resources. They were aware of nitrate run-off and soil erosion happening at their farms, especially during storm events can affect water quality in the Musquodoboit River. In addition, these latter farmers discussed different management practices and approaches they use to reduce their impact on water resources. For instance, a participant elaborated on the importance of timing during manure application:

> Well, we have to have our water tested once a year to make sure we have good quality water. Farming next to the river and ….we have to go by certain [rules] you can't be there in the winter time spreading manure. In certain times of the year, the ground is not frozen and it will soak in rather than wash off. – Farmer 7

5.3.4. Water quality impacts from other land uses

When asked about water quality challenges in the watershed, farmers also discussed other land use activities that they perceive to impact water quality (Figure 6). Overall, forestry practices were commonly observed (8/10) to result in soil erosion and contribute to flooding and subsequently affect water quality in the Musquodoboit River. Three farmers were also concerned about the release of untreated residential sewage into the Musquodoboit River. In addition, three farmers believed mining activities that take place within the watershed affected water quality. Among the five farmers who believed there are no water quality concerns, two farmers were unaware of any impacts from other land use activities while the other three farmers felt forestry practices are responsible for water quality concerns. After discussing other land use activities that take place in the watershed, half of the farmers (5/10) mentioned that farmers are being unevenly blamed for water pollution while other industries and practices also contributed to water pollution.

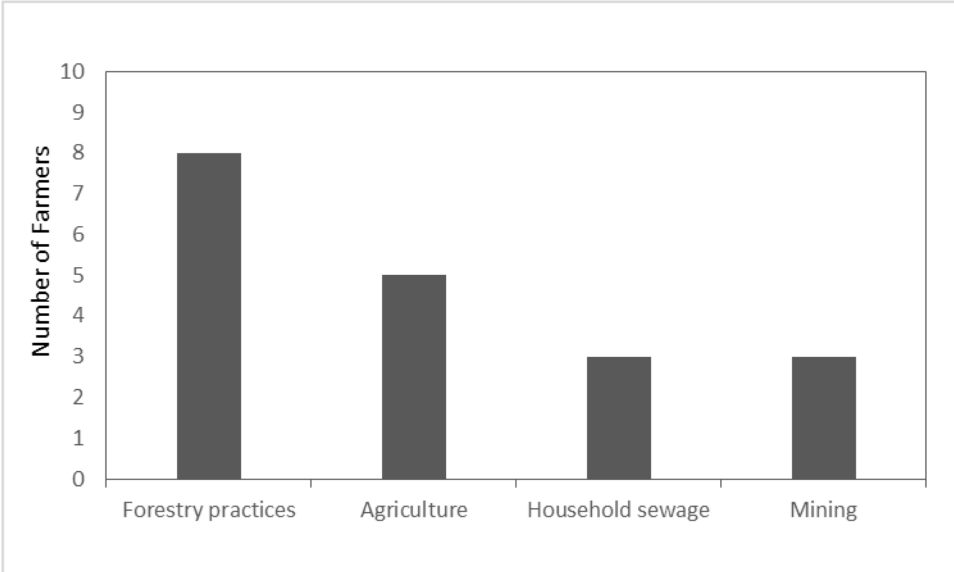

Figure 6. The most common land use activities that farmers perceived to impact water quality

5.3.5. Farmer opinion on regulations and agri-environmental programs

All farmers considered rules and regulations for farming as a necessity. In addition, farmers also argued that there should be a balance and regulations should not be a hindrance to their agricultural operations. When discussing scenarios and the need for balance, a participant made references to the Walkerton crisis that occurred in the town of Walkerton in Ontario, where drinking water was contaminated by bacteria from manure application in agricultural fields and resulted in the death of seven people and caused illness in 2,300 people (Hrudey & Payment, 2003) : "Nobody wants to see it over regulated, but everybody understands that we all don't want a Walkerton type event, like you know. There needs to be a balance." (Farmer 3). Some farmers (6/10) felt regulations and water management decisions are made without farmer participation and argued that decision makers do not take into account the economic losses faced by farmers.

> Agriculture is on the back burner. No one in government cares… I don't think anything is going to change. They are maybe going to put more restrictions on, as in you know, "You can't do this, you can't do that". And, no compensation or no thought to your livelihood. You know a lot of these decisions are made and they are made because one pressure group pressures the leaders or government to do something, without understanding the full consequences. – Farmer 2

5.4. Discussion

This study sought out to understand how Musquodoboit farmers perceive water quality, and their impact on it as farmers. Overall, we found that farmers had positive perceptions regarding the water quality of on-farm water sources. Musquodoboit farmers had varied opinions regarding the water quality of off-farm water sources. While half of the participants believed water quality challenges existed in the watershed and their agricultural activities contributed to it, others believed there are no water quality challenges and their agricultural practices did not contribute to it. Farmers considered forestry practices within the watershed to impact water quality more than agricultural activities. In addition, farmers expressed their opinions about existing environmental regulations and agri-environmental programs. It is important to clarify that we did not analyze the influence of farmer perceptions of water quality on their decision making. In the following section, we discuss these findings in-depth and analyze the implications of these findings to agri-environmental programs.

All farmers were satisfied with the quality of water from various sources within their farms. However, not all farmers tested their water annually. It can be argued that having access and control over these water sources allows farmers to be confident about water quality. Previous research has shown that organoleptic properties, particularly flavour plays a major role in shaping our perceptions of water (de França Doria, 2010). It is likely that farmers' perceptions of on-farm water quality was shaped by their interaction with on-farm water sources. Farmers had varying opinions on water quality within the watershed. Half of the participants were unaware of the water quality challenges occurring in the watershed, while the other participants identified ongoing water quality issues and potential threats. Several variables could have contributed to this difference of opinion. Prior experience, risk perception and context can influence public perceptions of water quality (de França Doria, 2010). Farmers who were aware of water quality issues often described interactions with various individuals and organizations that made them aware of the water quality issues within the watershed.

Half of our study participants believed that their agricultural practices do not affect water quality. Due to the diffuse nature of non-point source pollution it is difficult to convince farmers of their potential contribution to water pollution (Shortle & Abler, 2001). Especially, within a watershed where other land use activities are also prevalent, a farmer might believe that his/her contributions to water pollution is negligible. Most Musquodoboit farmers considered that forestry practices within the watershed had a negative impact on water resources, more than agricultural activities. In their study, Tomazic and Katz (2002) found that farmers were less likely than urban residents to view agriculture as a source of pollution. In addition, rural residents generally considered farming and timber harvesting to be a less significant source of pollution in comparison to urban residents (Tomazic and Katz, 2002). Differences in perceptions regarding polluters can result in conflicting priorities. However, it has been argued that conflict among stakeholders is expected in watershed partnerships and conflict brings about interest and passion, and if managed properly conflict can be used to stimulate citizen partnership (Zacharakis, 2006).

5.5. Implications for agri-environmental programs

Using our understanding of how Musquodoboit farmers perceive water-related ecosystem services, water quality, agricultural pollution, and how these perceptions could influence farmers' water management decisions, we make recommendations to agri-environmental programs.

5.5.1. Watershed-based partnerships

Multiple stakeholders including but not limited to farmers, residents, Halifax Water and The Nature Conservancy of Canada are interested in the welfare of water resources within this watershed. However, the goals of these stakeholders differ substantially and can create conflict. Previous research has demonstrated that top-down regulatory measures and extension is often ineffective and inappropriate to tackle agricultural pollution (Vanclay, 2004). Farmers in this study felt that water management decisions were being made without farmer consultations and farmers' concerns and views are not being accounted for. It can be inferred that farmers in this watershed are interested in participating in discussions on water management. Forming partnerships among multiple stakeholders and using local leadership can turn conflict into a positive force in watershed management (Zacharakis, 2011). It is recommended that interested local organizations begin by forming partnerships with the farming community. Identifying a liaison between the farming community and different organizations will serve as a good starting point.

5.5.2. Water quality testing and information transfer

Some farmers in our study were unaware of water quality issues within this watershed. Awareness can be increased through a water quality testing regime and information transfer. Water quality of watercourses in Nova Scotia is often untested; lack of information on water quality can delay or create inaction. Water quality testing should be conducted to understand causes of pollution and this information can be used to create awareness. Previous research has demonstrated that one-on-one information transfer is more effective than mass dissemination (Shepard, 1999). In this watershed, the total number of farmers is estimated to be around 15 – 20. Given the small number of active farmers in this watershed, one-on-one information transfer might be possible.

Farmers in this watershed are particularly concerned with the costs associated with flooding of the Musquodoboit River. Organizations should capitalize on this concern and invite farmers to participate in workshops where discussions on flooding and water resources can take place. Previous research has shown that the presence of trained extension officers often times improve communication with rural farmers (Bello & Obinne, 2012). Therefore, interested organizations should hire with trained extension workers.

5.5.3. Farmer led solutions and adaptations

Farmers in this watershed used beneficial management practices such as establishment of riparian buffers, cover crops and land abandonment to manage the disservice of flooding. Several barriers prevent the adoption of conservation agricultural practices by farmers (Knowler & Bradshaw, 2007; Vanclay, 2004). Some of the barriers include the need for additional learning and complexity of the practice (Vanclay, 2004). Extension efforts that focuses on existing solutions and adaptations eliminates the barrier of additional learning and further encourages farmer adoption. Certain practices such as, the establishment of riparian buffers and cover crops to reduce the impact of flooding, can improve farm profitability and enhance multiple ecosystem services. Organizations should promote these beneficial management practices through outreach and financial assistance. Organizations should offer more detailed advice to ensure that these practices are implemented effectively. For instance, farmers in this study had differing widths of riparian zones to manage the disservice of flooding and erosion. Providing technical advice on riparian area creation and management by conducting an assessment of existing riparian area health will likely increase effectiveness of this practice.

5.5.4. Payment for ecosystem services

Payment for ecosystem services (PES) is an innovative financial mechanism that provides compensation to people providing environmental services (Kumar & Muradian, 2009). Farmers located upstream can be compensated for establishing riparian buffers along the Musquodoboit River and adopting benign land practices that increase ecosystem services to users downstream. In Canada, the Alternate Land Use Services program is a community-driven environmental stewardship program that provides financial incentive for farmers to enhance ecosystem services (Campbell, 2014). However, there are several challenges with PES, such as the ability of PES to outweigh non-economic justifications for ecosystem services, the difficulties in quantifying and valuing ecosystem services, and most importantly the possibility of payments triggering perverse effects, where farmers adopt undesirable practices to obtain compensation (Kumar & Muradian, 2009).

Overall, understanding farmers' perceptions of water quality has provided us with information that can improve farmer engagement. It is important that organizations interested in farmer engagement consider multiple factors, such as farmers' awareness of water quality issues, their perceptions of different land use activities and their opinion on regulations and outreach programs, which influences farmer decision making and create outreach programs accordingly.

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CHAPTER 6 - CONCLUSIONS

This chapter provides a summary of the thesis and discusses key findings and important implications.

6.1. Project summary

In this thesis, I set out to understand farmers' perceptions, and the influence of different perceptions on farmers' decision making regarding on-farm water management. In particular, this thesis examined farmers' perceptions of water-related ecosystem services, water quality, and climate change. Some water quality challenges in the Musquodoboit watershed are attributed to non-point source pollution from agricultural activities, and my interest in farmer engagement inspired this thesis. The literature identifies several factors including farmers' perceptions that can influence farmer decision making. However, we have limited understanding of farmers' perceptions regarding water resources and how these perceptions influence management of water resources. Therefore, this thesis used map-driven semi-structured interviews to address the following research questions:

1) What are farmers' perceptions of water-related ecosystem services, and how do these perceptions influence decision making surrounding water management?

2) What are the different farm water management practices farmers use to manage the services and disservices arising from water bodies?

3) What are farmers' perceptions of climate change, and how does it influence their water management decisions?

4) What are farmer perceptions of water quality within the Musquodoboit watershed, and how do they perceive the impacts of their agricultural practices on water quality?

6.2. Key Findings

6.2.1. Farmer perceptions of ecosystem services and disservices

Overall, farmers in the Musquodoboit identified a set of water-related ecosystem services including freshwater provision, water purification by wetlands and recreational opportunities from water bodies as benefits. In addition, farmers identified water-related ecosystem disservices such as loss of arable due to flooding of the river and presence of wet areas, as costs to their agricultural operations. These farmers easily identified provisioning and cultural services from water bodies, and disservices that reduce agricultural productivity. However, farmers did not recognize the presence of certain regulating and supporting services, such as flood regulation by wetlands.

6.2.2. Farmer perceptions of water quality and climate change

Musquodoboit farmers had positive perceptions regarding their on-farm water quality. However these farmers had two different opinions on off-farm water quality and the contribution of agriculture to water pollution. Half of the farmers felt there were water quality challenges in the watershed and agriculture contributed to it and the rest disagreed. In addition, forestry practices were considered to have a negative impact on water quality in the watershed. Farmers in the Musquodoboit were aware of the phenomenon of climate change and observed changes such as increased precipitation and frequency of flooding. However, due to the limited scope of this thesis the impact of farmer perceptions of climate change on water management was not investigated in-depth.

6.2.3. Factors affecting farmer decision making

Farmers' perceptions of ecosystem services and water quality influenced their on-farm water management decisions. Farmers used management practices such as restricting livestock access to water bodies to protect the services they recognized. In addition, decision making was also influenced by individual farmers' production goals. For instance, some farmers used maladaptive practices such as farming close to the river to gain access to arable land. Finally, decision making was also influenced by the nature of the management practice under consideration. Overall, farmers' preferred cost-effective practices that required low maintenance.

6.3. Study Limitations

This study has certain limitations. Firstly, the small sample size of this study puts limitations on making generalizations. Moreover, this thesis relies only on information gained through interviews with farmers, there was no on-farm surveys or ground-truthing to verify different management practices being implemented. In addition, this thesis did not identify the social, economic, organizational and cultural factors that shape farmers' perceptions. Identifying these factors will further improve our understanding of farmers' decision making.

6.4. Future Research

This thesis focused on farmers' perceptions regarding water resources and their water management practices. However, we have limited knowledge on the ecological impacts that are occurring to the Musquodoboit River and other water bodies adjacent to agricultural operations. Future researchers can conduct stream rapid assessments (see: (Silvano et al., 2005)) on the Musquodoboit River to understand existing ecological impacts. Factors such as riparian zone condition, manure presence, water aspect and bank stability can be identified through quick visual assessments. This will identify ecological impacts and priority regions. This information can then be paired with farmers' perceptions and existing practices identified through this thesis for effective outreach.

6.5. Concluding Comments

Agricultural decision making is complex and is influenced by several economic, social, cultural, organizational, and institutional factors. Water management decisions are further influenced by farmers' perceptions of water resources. This thesis sheds light on farmer perceptions and the influence of perceptions on farmer decision making. Researchers and policy makers should continue to understand farmers' perceptions and provide accessible information to farmers that can help farmers to be allies in environmental protection, and that encourage farmers to adopt adaptive practices in the face of climate change.

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Appendix I - Interview Questions

I am going to be recording the interview. I will hold the tape recorder and I will begin by recording the date and time.
Do you have any questions before we begin the interview?

Map discussion Questions
Thanks for agreeing to participate in my study. We will start with a mapping exercise. In this exercise, we will use maps to discuss water management issues. I have some markers and stickers for you to use. If you have questions about the maps, feel free to ask me questions.
First, we will start with a map of the Musquodoboit watershed.

Watershed scale water management activities

1) I am new to the Musquodoboit Region. Can you help me orient myself? Can you show me approximately where your property is within this watershed?
2) This map does not show contour lines (water drainage); where does your farm drain into?
3) What areas have an impact on water within your property? Can you describe how the impacts to me?
4) Does your farm have an impact on water elsewhere within this region?
If another farm, what is your impact on them?
5) Do other farms drain into yours? If so, what is their impact on your farm?

This is great, now that I have a better understanding of where your farm is located within the larger watershed, we can move on to the map of your farm.

Farm scale water management activities

This is a map of your farm. I created this map using the PropertyIdentification (PID) Number(s) you provided for land you manage. It shows wetlands and land cover and property lines. Take some time to orient yourself. For this study, we have a very broad definition of water management; feel free to talk about any issues related to farm water management practice. We can start by identifying within this map, regions where farm water management challenges exist.

6) Can you use these stickers and markers to mark regions where you usually have a water management challenge?
7) Can you also explain the water management challenge to me? For every farm, water management challenges are different and I would like to know more about the specific issues within your farm.

(They could talk about a variety of issues, such as water supply, water quality, flooding and erosion concerns)

8) How often do these water management issues occur? Every year?
9) Do you think your neighbors face similar water management issues?
10) What do you think is causing this (name of water management issue) problem?

11) How have you been working around this challenge?

Thank you so much for identifying water management challenges within this map and explaining to me these challenges. I have a few more questions to help me understand how farming activities are affected by the presence of different water bodies.

12) What are some of the prominent water bodies within your farm, can you describe them to me?
13) Are these water bodies important to you and your farm? If yes, Why?
14) Do these water bodies provide any benefits to your farming activities?
15) Do these water bodies provide any costs to your farming activities?
16) How do these water bodies affect your farming practices?
17) Do you or your family use these water bodies for recreational purposes?
18) How long have you been farming in the Musquodoboit? (What has changed over the years when farming in the Musquodoboit region?)
19) Do you have a farming background? (If yes, have you farmed in other regions before?)
20) Are you concerned about water quality issues in your community?
    - How do water quality concerns affect your decisions on the farm?
21) What regulations apply to your farming practices?
    - How do you feel about them?

    At the time of the interview, the researcher will be well informed of the different policies pertaining to farming within Nova Scotia
22) What do you think about the provincial wetland policy?
    - Specifically, what do you think about the difference in regulations for maintaining riparian buffers for forestry and farming?
23) What do you think the future holds for farming in the region?
    - Is water management going to be a problem in the future?
    - Do you think the water management issues are going to get better or worse in the future?

That brings us to the end of the interview. It was great speaking with you, I learned a lot about different water management challenges in this region. If you would like I can send a report on the results of this study, once I complete data analysis. And, as I mentioned earlier, if you have questions feel free to call me anytime. Have a great day.

Appendix II - Letter for contacting farmers

DALHOUSIE UNIVERSITY
Inspiring Minds

School for Resource and Environmental Studies
Suite 5010, 6100 University Ave
Dalhousie University
Halifax, NS, B3H 4R2

[Date]
[Farmer Name and Address]

Dear [Farmer],
My name is Aiswarya Baskaran, and I am a Masters student at Dalhousie University, conducting research on farm water management issues within Musquodoboit, and I am requesting your participation in an interview. I am particularly interested in the Musquodoboit region, since it is the largest area of prime agricultural land within Halifax County. We are interested to understand water challenges faced by farmers in the valley, and help identify solutions based on farmers' own innovations. [Included if contact information was identified through key informants] Your name was referred to us by [Key informants name], when we contacted [Key Informant] to identify farmers who may be interested in water management issues and participating in our study. [Included if contact information was identified through Property Online] Your name and contact information was identified using your farm PID and the Property online database.

In order for the results to truly represent the thinking of farmers within the Musquodoboit region, it is important for us to get a wide range of opinions. We hope that you will help. There would be no need for preparation or prior study for this interview. I am hoping you will identify regions where you have water management issues within a map. You will also be requested to discuss your views on different water management issues facing the Musquodoboit region. Everything discussed will be confidential. It should not take more than two hours of your time.

I will be telephoning you soon to see if you are interested in participating in my study, if you are interested I will schedule an interview at a time convenient for you. If you have any questions or will be interested in participating, but will be difficult to reach by phone, please call me at my mobile number 902- 478 -9469. Or if you prefer please email me at ais.baskaran@dal.ca

Aiswarya Baskaran
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School for Resource And Environmental
Studies, Dalhousie University
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902-478-9469

Appendix III – Model Telephone Script

Interviewer– Can I speak to (name of farmer)?

Farmer - Hello, (name of farmer) speaking. How can I help you?

Interviewer - My name is Aiswarya Baskaran and I am a graduate student at Dalhousie University. I am currently conducting research on farm water management within the Musquodoboit region. I sent out a letter to you with some information about the study. Did you happen to read it?

As part of my thesis research, I am conducting interviews with farmers in the Musquodoboit region about water management issues. I was referred to you by (Key informant's name). As I understand you are farming in the Musquodoboit region, and I would like to speak with you about your perspectives on farm water management. Is this a convenient time to give you further information about the interviews?

Farmer - No, Call back later (agree on a more convenient time to call person back).

OR

Farmer - Yes, can you tell me a more about these interviews?

Interviewer- The interviews will be used to understand water challenges faced by farmers in the valley, and help identify solutions using farmers' own innovations. The interview will start with a mapping exercise, where you will be asked to identify different regions where farm water management challenges exist on a map of your farm. The interviews will be conducted at your farm at a convenient time for you. There is no prior preparation required for this interview. I expect the interviews to take a maximum of two hours of your time.

Do you have any questions regarding the study or the interview? If you are interested, I would like to email/mail/fax you an information letter which has all of the details we discussed along with contact names and numbers on it to help assist you in making a decision about your participation in this study.

Farmer– No, thank you.

OR

Farmer - Sure (get contact information from potential participant - mailing address/fax number/email address).

Interviewer - Thank you very much for your time. May I call you in 2 or 3 days to see if you are interested in being interviewed? Once again, if you have any questions or concerns please do not hesitate to contact me at my cell phone number 902-478-9469

Farmer - Good-bye. **Interviewer** - Good-bye.

Appendix IV - Informed consent form

DALHOUSIE UNIVERSITY *Inspiring Minds*

School for Resource and Environmental Studies
Suite 5010, 6100 University Ave
Faculty of Management,
Dalhousie University
Halifax, NS, B3H 4R2

Understanding farm water management issues within the Musquodoboit region

Researcher Contact Information

Primary Researcher

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902-494-1359

Dear [Farmer]

Thank you for agreeing to take part in an interview on water management issues in farming. These interviews will be used to inform the graduate student's thesis research project. Your participation in this study is voluntary and you may withdraw from the study at any time. The study is described below; it includes a brief description of the interview procedure and explains the risks, or discomfort you might experience. Participating in the study will not likely benefit you directly, but we might learn other things that will benefit others. Please discuss any questions or concerns with Aiswarya Baskaran.

Purpose of the Study

This study is designed to investigate the water management challenges farmers face and how it affects farming activities and the wider environment. Specifically, the study will focus on farmers in the Middle Musquodoboit River Valley. To create environmentally sustainable agricultural water management goals for the future, it is critical to understand the opinion of farmers and the water management issues they face. We hope that this study will allow us to better understand the water management concerns of farmers and will inform policy makers, watershed groups and citizens who are interested in water management.

Study Design

The study will involve interviews with farmers in the Musquodoboit River Valley. The study aims to recruit ten farmers from the Musquodoboit region. In-person interviews of approximately 120 minutes will be conducted at the farmer's property. A mapping exercise is involved in this study. A map of your farm and watershed will be presented to you to identify the areas that pose water management challenges. Information shared through the mapping activity will be taken back and digitized for analysis. After all interviews are over, personal identifiers in the map will be removed before use in analysis.

Who can participate in the Study?

You may participate in this study if you farm within the Musquodoboit River watershed. Participants are identified either by referral by key informants or by previous participants. Some participants are contacted by phone collected through the property online database.

Who will be conducting the research?

The principal researcher, Aiswarya Baskaran, will be conducting the interviews.

What you will be asked to do

You will be asked to participate in a mapping exercise and an interview. As part of the mapping exercise you will be asked to identify farm regions with water management issues on a map. An interview will follow to discuss the different water management challenges facing farmers. Interviews will be approximately 120 minutes in length.

Possible Risks and Discomforts

The risks and discomforts you will experience by participating in this study is expected to be minimal. Interviews will take place within your farm. All sensitive information is protected through aggregation of data. Raw spatial data from the mapping exercise will remain confidential and will not be used in publication or presentations.

Possible Benefits and Results

There are no anticipated results that will directly benefit you. However, you may benefit when knowledge gained from this study inform policy makers, and community and watershed groups, about water management issues faced by farmers. If you are interested in the outcome of the study, I will send out a brief report on the results through mail or e-mail.

Confidentiality and Anonymity

Your name will not appear in any publication or presentation. Your consent will be sought for using direct quotations, and a pseudonym will be assigned. All photographs will be taken only with permission. Your participation is confidential, only persons in charge will have access to your identity and to information that can be associated with your identity. Data (including maps and photographs) will be kept in a locked box at the School for Resource and Environmental Studies at Dalhousie University for five years and then destroyed.

There are limitations to maintaining the anonymity of the participants, as the farming population within the Musquodoboit River Valley region is quite small and the study uses referral as a method of participant recruitment. However, all information collected from the interviews will remain confidential and no personal identifiers that can identify an individual farmer will be provided in any report or publication

Problems or Concerns

If you have any difficulties with, or wish to voice concern about, any aspect of your participation in this study, you may contact Catherine Connors, Director, Research Ethics, Dalhousie University at (902) 494-1462, ethics@dal.ca

School for Resource and Environmental Studies
Suite 5010, 6100 University Ave
Faculty of Management,
Dalhousie University
Halifax, NS, B3H 4R2

Understanding farm water management issues within the Musquodoboit region - Informed Consent

I understand the information provided to me. I have had the opportunity to discuss the study and ask questions. I understand that I will receive no compensation for participation. I understand that my participation in this study is completely voluntary and I may withdraw from this study at any time or decline to answer specific questions. I am eighteen years of age or older. I understand that I will receive a copy of this consent form. I agree to participate in this study under the conditions stated above, with the specific permissions indicated below.

I give permission to the researcher to tape record my responses along with taking notes.	YES	NO
I give permission to the researcher to use information shared by me in the mapping exercise to create a compilation map for spatial analysis purposes. No raw data will be shared.	YES	NO
I also give permission to the researcher to use direct **quotes** from our interview anonymously in publications/presentations.	YES No need to ask	NO Do not use them
I authorize the researcher to take some photographs of my farm landscape during the interview	YES No need to ask	NO Do not use them
I give permission for pictures of my property taken by the researcher to be used in publications/presentations	YES No need to ask	NO Do not use them

Name: ___________________________ Signed:_____________________________

I certify that the informed consent procedure has been followed and I have fully answered all the questions the participant had

Researcher: Aiswarya Baskaran

Date:________________________________ Signed:______________________________