Running head: THE VALUE OF SHELTERBELTS TO PRAIRIE AGRICULTURE

FROM CULTURAL TO SUPPORTING ECOSYSTEM SERVICES,
THE VALUE OF SHELTERBELTS TO PRAIRIE AGRICULTURE, CANADA

By

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We accept this thesis as conforming
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Abstract

Shelterbelts were established in the Canadian Prairies as a means to protect soil from wind erosion. Knowledge gaps remain about shelterbelts’ ecosystem services to the agro-landscape, hence hiding farmers’ trade-offs in a changing agriculture. This research first investigated shelterbelts’ effect on soil biological activity and fertility. Soil samples were collected in September 2012 from sheltered and non-sheltered fields in the Rural Municipality of Stanley, Manitoba. Results showed that shelterbelts promote higher soil biological activity, potentially correlated to the enhanced organic matter and micro-climate adjacent to shelterbelts. A survey was then conducted to explore shelterbelts’ cultural services to the local community. Results indicated that while shelterbelts were perceived to significantly benefit community well-being, they were mainly recognised for agricultural functions. We conclude that shelterbelts are a significant element of both supporting and cultural ecosystem services, contributing to the prairie agro-system resilience. Further research and quantification of shelterbelts’ socio-ecological services is recommended.

Key Words: Shelterbelts, ecosystem services, soil health, cultural services, socio-ecological system, landscape conservation practice, prairie
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Introduction

The practice of shelterbelt, defined as the integration of tree rows in the farming system, was established in the prairies to reduce wind and protect soil from erosion (Kulshreshtha, Knopf, & Kort, 2003). During the early settlement of the Prairie Provinces in the 1850s, the extreme winds and temperature variations were seen as major limitations to agriculture. The government of Canada recognised the need for trees to lessen the effect of climate and soil drifting and created in 1901 The Indian Head Shelterbelt Center to provide seedlings without charge to Prairie settlers (Kulshreshtha et al., 2003).

A Vision for Sustainability

The way agriculture shapes the landscape and manages natural resources is critical to agro-ecosystem sustainability. Negative tradeoffs between production, ecosystem conservation and community livelihood can significantly heighten the agricultural system vulnerability to crisis and disturbances such as drought or floods (Power, 2010). This is particularly relevant to prairie agriculture, a region predicted to be strongly impacted by climate change. Researchers in natural resources management are encouraging agricultural practices that increase agro-ecosystem resilience, and the adaptive capacity of prairie communities (Swanson, Hiley, Venema & Grosshans, 2007). A main strategy in agro-ecology is to develop the complementarities and synergies that results from various combinations of crops, trees and animals in spatial and temporal arrangements (Altieri, 1999). Innovation related to soil and water conservation, such as agroforestry or intercropping system can increase the production of ecosystem services, thus enhancing the system’s resilience and adaptive capacity in the current climate.
change situation (Tarnoczi & Berkes, 2010). Better understanding of the agro-landscape ecological interactions and services that contribute to our well-being and development is critical to enable a transition towards a sustainable agro-system, one that serves joint production, conservation and livelihood goals (Millenuim Ecosystem Assessment, 2005).

**Changing Agriculture**

Soil protection has traditionally been a strong focus of prairie farmers and governmental programs (Kort, 1988). Prairie agriculture is however experiencing significant changes that heighten the tradeoffs between production, conservation and livelihood, particularly impacting on permanent conservation practices including shelterbelts. Since the rise of industrial agriculture, shelterbelts are regarded as traditional and in opposition with modern agricultural practices. The increase in land value coupled with investments in farm technology (GPS guidance, tile drainage, irrigation) and the wide adoption of minimum tillage have encouraged farmers to remove shelterbelts from their farm operations (Prairie Farm Rehabilitation Administration, 2000). Industrial agriculture primarily focuses on agro-ecosystem provisioning services, the end products of agriculture reflected by a market value such as crops. On the other hand, little attention is given to the non-marketed supporting and regulating ecosystem services, which are the agro-ecosystem fundamentals functions and processes that enable the sustainable production of goods (Sandhu, Wratten, & Cullen, 2010). Additionally, business orientated agriculture fail to recognize the inherent social and cultural bond that exists between rural populations and the agro-landscape, resulting in a looser connection with the ecosystem. From a social perspective, monoculture agricultural land is alienated from the major part of society, dominated by external markets and governmental planning procedures (Mayer
& Frantz, 2004). Farming landscapes have functions for broader groups in society but these are rarely acknowledged and valued. Ecosystem cultural services provide people with intangible benefits such as aesthetic, spiritual, recreational and educational opportunities, which directly benefit the community through improved living conditions, comfort, health, and social integration and cohesion (Dosskey, Wells, Bentrup, & Wallace, 2012). For example rural residents may identify themselves with the natural and cultural heritage of `their' territory, even if it is privately owned.

**Research Significance**

The removal of shelterbelts from prairie agriculture raises concern among rural populations (PFRA, 2000). Shelterbelts’ contribution to prairie agro-ecosystem resilience and community well-being is however poorly documented and therefore under-valued in decision-making. Beyond the acknowledgment that shelterbelts contribute to soil protection (Altieri, 1999), important knowledge gaps remain in the Canadian prairies about the benefits of agro-landscape physical complexity and ecological interactions between trees and crops, especially between below and above ground biodiversity (Thevathasan & Gordon, 2004). Given the ecological services provided by soil biodiversity to agriculture for soil fertility and productivity, knowledge of the structure and function of below-ground food webs and their temporal and spatial variation is crucial to the design of farming systems that preserve and take advantage of biodiversity for their fertilizing strategy (Giller, Beare, Lavelle, Izac, & Swift, 1997). Additionally, the lack of community knowledge and awareness about shelterbelts’ functions and services to the social, cultural and natural environment is a major issue. Shelterbelts’ external benefits to society need to be identified and expressed in order to weight in the decision-
making process. Further research about the effect of field shelterbelts on soil health based on biological indicators, and the derived ecosystem services produced for community well-being, is needed in order to evaluate the tradeoffs and consciously design efficient and sustainable prairie farming systems (Dosskey et al., 2012).

**Research Questions and Objectives**

Focused on the Rural Municipality of Stanley, this case study evaluated shelterbelts’ significance to prairie farming communities’ sustainability based on supporting and cultural ecosystem services. Firstly we questioned whether shelterbelts contribute to the soil biological activity and fertility of adjacent fields. By examining the ecological interaction between trees and soil biological activity, we hope farmers will have a better understanding of some of the supporting services that shelterbelts facilitate, and how they contribute to soil fertility.

Secondly we investigated the significance of the social and cultural services provided by shelterbelts to the local community. The lack of knowledge of the conceptual link that exists between soil management, soil health and public benefits in the agricultural landscape results in undesirable trade-offs. We hope that an evaluation of shelterbelts’ beneficiaries and net social benefits will help land managers and authorities understand these links, thus facilitating informed decisions about agro-landscape sustainable management for joint production, conservation and livelihood goals.
Literature Review

Prairie Sustainability in Manitoba

In this research, sustainable agriculture is defined as a system that jointly enhances productivity and rural livelihoods while conserving ecosystems (Scherr & McNeely, 2008). Indicators used to assess a system’s sustainability include vulnerability, resilience and adaptive capacity (Swanson et al., 2007). System vulnerability is the degree to which it is likely to experience harm due to exposure to a shock or stress such as climate change. System resilience is the capacity to absorb disturbances and rearrange itself while undergoing change so as to retain essentially the same functions, structure and processes. Finally, a system adaptive capacity represents the ability of the actors to respond successfully to change, and includes adjustments in both behaviour and technology in order to influence the system resilience (Swanson et al., 2007).

The Southern Manitoba agro-system is highly vulnerable to environmental degradations due to the extreme variations of temperature and precipitations conditions combined with strong wind exposure. As a result, issues related to the desiccation of organic soil and soil cover as well as water storage capacity can be significant (Swanson et al., 2007). This region is also highly sensitive to climate change. Prairie agriculture and communities are expected to experience altered precipitation patterns combined with longer and warmer growing seasons. Shortage of water supplies, intensified drought and flood events as well as heightened weather variability are predicted to stress farming communities (Tarnoczi & Berkes, 2010). In 2007, an extensive research project commissioned by the Canadian Government to evaluate prairie agriculture sustainability, concluded that prairie agriculture and communities should focus on building more
resilient agro-landscape, and raise community adaptive capacity in order to overcome climate change effects and sustain productivity (Tarnoczi & Berkes, 2010).

The development of industrial agriculture and general increases in land value is however changing prairie agriculture toward larger scale farm operations with an increase focus on financial return. A review of prairie agriculture by the Prairie Farm Rehabilitation Administration (PFRA) conducted in 2000 showed that between 1981 and 1996 the number of farms in the prairies decreased from 521,000 to 413,000, while individual farms became larger. Changing farm practices towards more mechanised and simplified systems are shaping agricultural landscapes, often to the detriments of environmental and social capital (PFRA, 2000). This is well shown by the farming practices used to prevent soil erosion. Soil conservation has been a strong focus of prairie agriculture since the era of the 1930s ‘dustball’ and recognised as a major contributor to agriculture and community sustainability. Permanent conservation practices such as grassed waterways, shelterbelts, and strip cropping were adopted to control wind and water erosion. Today many farmers have switched from permanent conservation practices to crop residue or resistant soil surface such as zero till (PFRA, 2000). Minimum tillage as a replacement strategy is usually, but not always, effective depending on the annual precipitation pattern, soil moisture and crop residue production. Environmental disturbances and stresses such as drought are infrequent events but can cause severe damage and costs.

**Ecosystem Services Approach to Agro-landscape Management**

Researchers around the world expressed concern about industrial agriculture models intensifying the negative tradeoffs between production, environmental
conservation and rural community welfare (Scherr & McNeely, 2008). In parallel, agricultural lands are increasingly perceived by society as multifunctional in that they can be managed for commodity production and simultaneously provide beneficial environmental amenities such as carbon sequestration, wildlife habitat, recreational opportunities, open space, and improved aesthetic quality of the land (Grala, 2012). The concept of ecosystem services was created in the 1970s and enabled decision-makers to measure the benefits obtained from ecosystems and highlight the trade-offs between land-uses, beneficiary and ecosystem services themselves (De Groot, Alkemade, Braat, Hein, & Willemen, 2010). Ecosystem services are defined by the benefits obtain from the ecological functions and the interrelated biotic and abiotic processes upon which human well-being and development greatly depend (MEA, 2005). The Millennium Ecosystem Assessment (2005) distinguished between provisioning, regulating, supporting and cultural services. Typically, provisioning services are expressed in a good’s market value because they are products of nature such as grain, timber or fuel. On the other hand, regulating, supporting and cultural services are usually non-marketed services (De Groot et al., 2010). Supporting Services are the basis for primary production, soil formation and nutrient and hydrological cycling. Regulating services take into account ecological processes such as climate regulation, flood attenuation, or disease regulation. Finally, cultural services represent the human values obtained from nature such as aesthetic, spiritual or recreational values. Thanks to this concept, the ecological, social and economic benefits generated from investments in conservation and restoration of ecosystems gained greatly in visibility, increasingly perceived as a “win win” situation by land managers and policy-makers (De Groot, 2007).
An important aspect of ecosystem services is the ability for environmental managers to enhance the agro-landscape capacity to produce multiple ecosystem services (Dosskey et al., 2012). Research in agro-ecology found that the physical complexity of the agro-landscape is highly correlated to the provision of multiple services to agriculture, conservation and rural communities. It is therefore critical to maintain high landscape interaction using natural habitat mosaic and landscape biological connectivity (Dosskey et al., 2012). Crop productivity for example is enhanced by pollination and natural biological control for pest and disease, which depend crucially on spatial structure of the landscape. Simultaneously, rural populations gain in social cohesion and well-being thanks to the recreational and spiritual opportunities linked to the proximity of nature (Altieri, 1999). It is important however to acknowledge the subjectivity of the ecosystem services concept, as the valuation system depends on perceived human benefits. Conflict may occur when people have different utilities or competing preferred ecosystem services (Robinson et al., 2012). Impacts on surrounding communities, such as net public benefits, should therefore be weighed more heavily in land use decisions than impacts on owners and stakeholders of the land.

**History of Shelterbelts**

Shelterbelts are found in most agricultural parts of the world. They are closely related to the development of agriculture and serve a variety of purposes depending on their location (Burel, 1996). Over time, the structure of trees in the landscape becomes the countryside, portraying to the community cultural practices and identity. As a consequence the subject of shelterbelts should not be studied without considering the farming systems and the rural society as a whole. They are man-made, part of rural
landscapes, and their species composition depends on the history of the countryside, as well as current farming practices (Burel, 1996).

Shelterbelts can sometimes be related to agroforestry or intercropping systems, where the associated crop, tree and/or livestock production aims at increasing total production (Nair & Gholz, 1987). These systems have been traditionally used in tropical regions and are increasingly perceived in temperate regions as more productive and sustainable than conventional systems (Thevathasan & Gordon, 2004). Most of the time however, shelterbelts are integrated to farming systems to serve single or multiple purposes depending on the agricultural region and the cultural group they are linked to. Shelterbelts were established in the Northern America largely to protect soil, crop and people from wind storms (Kulshreshtha et al., 2003). In Europe, shelterbelts are often referred to as hedgerows because they tend to mark the fence line between properties or fields (Burel, 1996). In previously forested ecosystems such as Australia, shelterbelts can be remnants serving as biological corridors and habitat for the native flora and fauna (Bird, 1992). In traditional pastoral areas shelterbelts are often used for livestock protection, source of food, timber and medicine (Jackson, Pascual, & Hodgkin, 2007). Finally, one universal function of shelterbelts might be their positive impact on the visual appearance of agricultural landscapes (Grala, 2012).

Shelterbelts’ Ecosystem Services to Agriculture

From an agronomist’s perspective, studies have demonstrated since the early twentieth century that field shelterbelts benefit crops growing in their shelter (Kort, 1988). Extensive research was conducted in Canada to quantify the increase in crop and forage yield due to reduced wind erosion, improved microclimate, snow retention and
reduced crop damage by high winds (Kort, 1988). Shelterbelts help reduce temperature and increase air moisture through evapotranspiration, hence preventing over heating from dry hot winds during summer (Kort, 1988). The shelterbelt orientation, height and longevity as well as the field width also influence the effectiveness of shelterbelts on crop yields. Kort (1988) found that weather conditions determine the level of crop responsiveness to shelterbelts. Generally, the percentage yield increases due to shelterbelts is higher in drier regions or in drier years. Different crops will also vary in their responsiveness to shelter. For example winter wheat, barley, rye, millet, alfalfa and hay appear highly responsive to its protection compared to spring wheat, oats and corn which respond to a lesser degree (Kort, 1988). The success of Tree-Crop systems depends on the ability to maximise beneficial interactions, while reducing competition. The pattern of these interactions however changes with time, as the trees grow horizontally and vertically. It is therefore important to understand and manage the trees’ ecological interactions, using proper species selection and management techniques (Thevathasan & Gordon, 2004).

The majority of studies on shelterbelts’ services to agriculture are based on chemical indicators of soil health and crop yield such as organic matter. There is however a need to evaluate shelterbelts’ services based on ecological indictors. Indeed, ecological interactions are the source of many agricultural services. Thevathasan & Gordon’s (2004) research on ecological interactions in intercropping systems in Ontario found that the ratio of predatory insect, bird population, earthworms, soil carbon and nitrogen were higher in intercropping systems than conventional ones. Many ecosystem services are derived from biodiversity, including pest management by predatory insects and birds,
pollination of crops, improved soil structure and stability from earthworm activity and a more efficient nitrogen cycling (Thevathasan & Gordon, 2004). The author concluded that trees can have an ameliorative effect on biodiversity which benefits the system. Furthermore, shelterbelts represent a network of biological connections at the landscape scale, hence influencing many landscape ecological functions and processes. Both natural biological control services and pollination services depend crucially on the movement of organisms across the agricultural landscape. Bird (1992) found that shelterbelts located at less than 1km away increase crop pollination and yield by 15% to 40%. Studies from France and Russia demonstrated that a network of shelterbelt is 30% more effective than an isolated tree row at reducing wind. Shelterbelts should therefore be managed on a landscape scale rather than field scale in order to optimise the services produced (Burel, 1996).

**Shelterbelts Supporting Ecosystem Services**

Important knowledge gaps remain about shelterbelts’ contribution to soil fertility. Shelterbelts’ supporting services have only recently raised attention, partly due to the limited recognition that above and below ground biodiversity play a key role in determining the properties and productivity of soils, and partly due to the difficulties in identifying the huge diversity of soil organisms and establishing direct links to soil function (Barrios, 2007). Additionally, supporting services for soil fertility has largely been replaced by human inputs (i.e., soil tillage, fertilizer and pesticides) that ultimately depend on non-renewable energy sources (Barrios, 2007).

Below-ground organisms are a promising source of ecological services for humus formation, soil structure, and nutrient cycling (Lavelle, 1997) and many researchers
believe they could directly contribute and support new biologically fixed fertilizing strategies (Barrios, 2007). Maintenance of soil organisms and their proper functioning as regulators of nutrient cycling are proven to contribute to soil health and fertility (Anderson, 2003). Furthermore, Lavelle (1997) argues that soil micro-organisms, roots and invertebrates have complementary adaptive strategies whereby they influence three major processes in soils i.e., decomposition and the dynamics of soil organic matter, the formation and maintenance of the soil structure, and nutrient and water supply to plants.

If there is a direct link between above-ground plant diversity and below-ground biodiversity, then enhanced plant diversity above-ground will contribute to the re-establishment and multiplicity of soil organisms being able to carry out essential biological functions (Giller et al., 1997). Clapperton (2004) concludes that integrating cropping practices that increase plant diversity such as agro-forestry and diversified crop rotations can therefore increase the potential for enhanced biological fertility by varying the quantity and quality of plant litter (Clapperton, 2004). Significant knowledge gaps remain however about the the importance of interrelationships between soil biota, plants and soil management practices for regulating soil processes. Further research is needed to determine whether shelterbelts contribute to promote a suitable habitat for living organisms to thrive and cycle nutrients due to the influences on physical structure and biotic properties.

**Soil biology activity indicators.**

**Earthworms.**

In this study shelterbelts’ supporting services are focused on soil formation and nutrient cycling. A good indicator of soil formation and nutrient cycling is earthworms
Earthworms are the main components of *Macrofauna* and are useful indicators of soil health. Considered to be ecosystem engineers, they can modify the physical, chemical, and biological properties of soil, and contribute to nutrient cycling, soil aeration and water infiltration. They benefit soil structure and stability by digesting soil organic matter, adding 80-120% water to the ingested soil and 5-38% of the dry weight of soil as mucus, a readily assimilable substrate (Lavelle, 1997). Additionally, studies have shown that earthworms can affect the species composition of microorganisms, including protozoa in the soil and around the roots of plants. Their ability to dig the soil and create specific structures for their movements and living activities (e.g., burrows, galleries, nests and chambers) greatly influences microbial activities (Lavelle, 1997). Such interactions are important for nutrient cycling and plant productivity.

Very few studies about the effect of shelterbelts on earthworms have been conducted in Canada. Thevathasan (2004) explored the interaction between intercropping and earthworms in Ontario. Results indicated that the earthworm population and biomass was much greater underneath Ash trees (379 earthworms/m²) compared to Maize fields (11 earthworms/m²). Earthworms were correlated to bulk density, decomposition of organic matter and nitrogen release, confirming their contribution to soil formation and fertility (Thevathasan & Gordon, 2004). No data within the Canadian prairie was found, probably due to the low presence of earthworms in this region. The ice ages are thought to have destroyed native earthworms wherever glaciers covered land; hence, of the twenty species of earthworms found in Canada, two are native to Northern America and the eighteen others have been introduced by Europeans (Clapperton, 2004).
Despite these limitations, earthworms were still chosen in this study as an indicator of soil biological activity, partly because they are well recognized and appreciated by farmers for their contribution to soil structure and fertility.

**Microbial Biomass Carbon.**

Soil microbial biomass carbon (MBC) is the measure of carbon derived from all microorganisms in a given weight of soil (Wojewoda & Russel, 2003). Similarly to earthworms, MBC is considered a good indicator of soil formation and fertility because it responds quickly to soil changes, is a key element of soil structure, soil humus formation and nutrient cycling, and is strongly correlated to organic matter and available nitrogen (Wojewoda & Russel, 2003). MBC typically represents 1-5% of the total soil organic carbon, while microbial N forms 1-6% of total soil organic nitrogen (Sparling, Pankhurst, Doube, & Gupta, 1997). Micro-organisms facilitate nutrient availability through decomposition of detritus and plant residues and through nitrogen fixation. They also have the ability to stimulate nitrogen mineralisation and release ammonium from predation on micro-organisms nitrogen (Lavelle, 1997). They also form symbiotic associations with roots and act as barriers to pathogens (Sparling, 1997). In agricultural terms, it translates into improved resilience to climate change and environmental degradation, food and nutrition security, and improved livelihood (Barrios, 2007).

MBC is usually concentrated in the top few centimeters of soil (over 0-15cm) and declines rapidly with depth. Their inability to move in the compact soil environment limits their activity to the immediate microsite in which they reside. They are dependent on larger organisms, roots and soil fauna such as earthworms, for access to new substrates (Lavelle, 1997). Agricultural or land disturbance significantly impacts MBC.
For example MBC is consistently lower in conventional rather than in organic and low-input plots (Sparling et al., 1997). An experiment by Bloem (1994) showed that after skim ploughing (Day 234), the bacteria increased quickly from about 10 to about 20 kg C ha. The bacteria returned to the original level of about 10 kg C ha-- cm-t depth within 2 weeks. These peaks in microbial growth can probably be attributed to an increased availability of organic matter due to soil mixing by the cultivator (Bloem et al., 1994). Additionally, microbial communities are influenced by many environmental variables such as soil type, pH, moisture and temperature, as well as the nature of food resources (Sparling et al., 1997). It is therefore important to consider the time of the year and the farming operations when sampling for MBC.

No literature on the effects of shelterbelts on microbial activity in adjacent fields was found from Canada. A series of research projects on the impact of shelterbelts on soil biological, physical and chemical properties was however conducted in Poland between 1999 and 2007 (Wojewoda & Russel, 2003). Wojewoda & Russel (2003) found that MBC was highest in the shelterbelts and decreased with distance in the adjacent fields. Organic matter and MBC were significantly correlated. Changes of soil properties as an effect of agroforestry practices were also documented, mainly explained by the accumulation of large amount of organic matter from falling leaves and animal waste. A method often used to determine MBC is Chloroform Fumigation-Extraction; this is explained in the Method section. The results should be expressed in volumetric rather than in weight basis as it compensates for changes in soil bulk density (Sparling et al., 1997).
Soil fertility indicators.

Among soil fertility indicators, organic matter and mineralized organic nitrogen are considered useful indexes (Anderson, 2003). Organic matter is composed of the living biomass of microorganisms, fresh and partially decomposed residues, and humus. In stable soils, humus dominates the soil organic matter composition. Thus most of the benefits and properties of soil organic matter relate specifically to humus which retains the soil structure, avoids soil erosion, promotes microbiology activity, stocks and delivers important nutrients for plant growth (Anderson & Domsch, 1989). Organic matter acts as a binding agent between soil particles, facilitating aggregate stability, which is critical to soil health and fertility.

The microbial mineralization of organic nitrogen has been suggested as a useful index because both the accumulation and mineralization of nitrogen in soil are predominantly biological processes (Sparling et al., 1997). Nitrogen mineralization is therefore a very useful indicator of both organic matter quality and microbial processes in soil, particularly to land users interested in high levels of available nutrients and soil organic nitrogen reserves for plant production (Smith & Michalyna, 1973). Wokewoda’s (2003) study on the effects of shelterbelts on soil organic matter showed that organic matter was two times higher in the shelterbelt soil compared to field soil. Soil organic matter and organic nitrogen showed a regular pattern along the gradient from the shelterbelt to the middle of the field. The study suggests a favourable effect of shelterbelts on organic matter content in adjacent fields (Wojewoda & Russel, 2003).
Agro-landscape Resilience

From an ecological perspective, shelterbelts are a perennial element of the landscape that facilitate above and below ground flux for air, water, nutrients, carbon sequestration and biodiversity (Altieri, 1999). The homogenous nature of agricultural landscapes generally reduces biodiversity, hence reducing the ecosystem health and resilience (Altieri, 1999). This can be partly compensated by developing refuges such as field margins which can particularly benefit invertebrate species (Bird et al., 1992). Shelterbelts are important reservoirs of organisms, although this has rarely been directly evaluated (Tsitsilas, Stuckey, Hoffmann, Weeks, & Thomson, 2006). Thevathasan (2004) found that the intercropping system was particularly beneficial for birdlife, providing forage and nesting opportunities for local and migratory birds. Overall, the external benefits derived from the biophysical changes caused by shelterbelts have been valued over 140 million by PFRA, counting for carbon sequestration, reduced soil erosion and biodiversity, water and air quality services. It also includes health values, transportation safety, aesthetics and property values (Kulshreshtha et al., 2003).

Shelterbelts Cultural Ecosystem Services

Shelterbelts often act as a safety net, a refuge or a buffer to external aggressions. The prairie can be a very hostile environment. Besides protecting rural residents from extreme weather conditions, shelterbelts help energy efficiency by reducing bills by up to 25% and providing renewable energy to warm homes and buildings (Swanson et al., 2007).

Socially pleasing, shelterbelts have long been noted for their ability to diversify otherwise homogenous agricultural landscapes. Kulshrestha et al. (2003) conducted an
inventory of shelterbelt’s public and private goods. Prairie communities and farmers were surveyed about their perceived values of shelterbelts. Benefits included improved air, water, biodiversity, energy, amenities, transportation and health benefits. An estimation of soil, air and water resources, biota and improved economic benefits was provided with an associated monetary value. There was however a lack of research and information regarding the non-production values of shelterbelts to different beneficiaries. A vague description of shelterbelts’ contribution to well-being due to the proximity of trees and nature was mentioned but not quantified. Grala’s (2012) study on the rural communities’ willingness to pay for shelterbelts based on aesthetic values was the most informative found within prairie regions.

Other parts of the world such as Europe and Asia have documented the role which shelterbelts can play in shaping regional sociocultural identity and renown (Burel, 1996). Trees are a trans-generational element of the landscape. They can represent a family legacy, imprinted in the landscape as landmarks. This sense of ownership is shared by members of the community, hence becoming part of the collective identity (Mayer & Frantz, 2004). Such cultural dimension has been well valued and integrated into land management in Europe where regional landscapes play a strong role in the local community’s heritage, values and identity. Some agro-landscapes have maintained their network of trees for centuries, conserved by local farming practices (Burel, 1996).

Hence the conservation of shelterbelt in the prairie might depend on a greater appreciation of the cultural services they provide to the community and farmers. The socio-cultural dimensions of shelterbelts to prairie communities are still to be expressed. Few studies have mentioned the significance of prairie landscape as a reflection of prairie
community, cultural values and identity (Swyripa, 2010). Shelterbelts however have been planted by the first prairie settlers and have been maintained over generations, providing a sense of countryside and boundaries to an otherwise open space (Swyripa, 2010). The cultural services provided by shelterbelts may be significant to the rural communities’ well-being. Verbalising intangible services such as cultural identity and well-being are important, because they contribute to the health and social relations of a community, an important predicator of community adaptive capacity and sustainability (MEA, 2005).

**Social-ecological Systems, a Focus on the Human Factor to Achieve Agriculture Sustainability**

Agricultural systems can be considered as socio-ecological systems where farmers’ knowledge is holistic, incorporating socioeconomic, cultural, political, and agroecological factors (Mauro, McLachlan, & Van Acker, 2009). Local knowledge (LK) of farmers is experience based and represents a rich and reliable source of information regarding the impacts associated with agricultural design, technology and practices (Mauro et al., 2009). In a study on perceived risks towards genetically modified wheat, Mauro et al. (2009) found that farmer attitudes toward risk, trust, and experts regarding agriculture is highly influenced by their expertise of these agroecosystems and the socio-cultural factors embedded in rural communities. Environment and community concerns were particularly important in the perceived risks associated with agriculture, showing that environmental, social, and economic risks are inextricably intertwined. The cultural values and practices of the local communities greatly influence the integrated management of ecosystem services as part of their production system such as the maintenance of a complex agro-landscape (Burel, 1996). Farmers’ expertise continues
however to be overlooked by decision makers and regulators across North America (Mauro et al., 2009).

Leopold (1949) wrote years ago "We abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect" (p. viii). Fostering sustainable ecological and economical behavior might be achieved by cultivating a greater sense of connectivity, requiring to work through and across existing belief systems. Connection to nature is an important predictor of ecological behavior and subjective wellbeing (Mayer & Frantz, 2004). As closeness increases, so does empathy and willingness to help. The impact that direct experience has on increasing affective relationship with nature may therefore have a stronger impact on ecological behavior than more knowledge-based information (Mauro et al., 2009).

Explanations of environmental values include the cultural bias theory, defined as the extent to which an individual feels incorporated into bounded units (group) and the extent to which an individual’s life is governed by externally imposed rules. Differences in connectivity with nature arise not so much from knowledge of natural resource economics as from an intuitive sense of sameness with the world around us (Dutcher, Finley, Luloff, & Johnson, 2007). Measuring and understanding our relationship to cultural values of nature and how our identity is shaped by the natural environment, in this case to shelterbelts is therefore important (Dutcher et al., 2007).

The adoption of an integrated farming system with joint production, conservation and livelihood goals requires a philosophical shift, one where the distinction between farming, conservation and culture is lessened. Canadian prairie communities may lack the
inbuilt appreciation for the economic and ecological relationships and mutual interdependence among agriculture, biodiversity and ecosystem services that traditional societal systems have developed overtime (Scherr & McNeely, 2008). In the physical landscape, this means that natural resource managers and farmers need to purposely identify the most appropriate physical complexity for an area to effectively deliver and sustain the range of services required (Mattison & Norris, 2005). Investments in conservation, restoration and sustainable ecosystem development needs to be seen as a “win win situation” which generates substantial ecological, social and economic benefits (De Groot et al., 2010).
Material and Methods

Study Area

The study was conducted in the Rural Municipality of Stanley, located in Southern Manitoba (Appendix A). This municipality was chosen as the study site because of the high number of shelterbelts, its dynamic agricultural community and willingness to collaborate in research projects. The presence of well-established local organizations related to agriculture and conservation made it an especially fertile ground for participative research. A census conducted in 2011 indicated that the municipality had approximately 8,500 inhabitants distributed between several residential villages and scattered acreages. Winkler and Morden, respectively 10,000 and 7,000 inhabitants are the closest towns. Agriculture is the main land use of the area, which is part of the fertile western section of the Red River Valley Plain, with some of the most productive soils of the province for producing a wide variety of crops (Smith, & Michalyna, 1973). The soils are 7,000 to 8,000 years old, and dominated by Gleyed Black (75%), Orthic Black (15%), Gleyed Cumulic Regosols (8%) and Gleyed Saline Blacks (3%). Soils are strongly calcareous with an alkaline pH of 8 and a texture from moderately coarse sandy to very fine clayey and an organic matter content of 3-4% (Smith, & Michalyna, 1973). Surface run-off and internal drainage is slow due to permeability of 75% of the soils in the area. Soil Capability Classes is I to III. The climate is cool sub-humid continental. Frost free periods are among the highest of the province. Precipitation is highly variable, from 6 to 20 inches yearly, and mainly occurs between May and October. The native vegetation comprised of tall prairie, meadow-prairie grasses and herbs has largely
disappeared due to cultivation. Native bush and shrubs include aspen, oak, elm, ash, Manitoba maple, hazel, dogwood, and willow along streams (Smith, & Michalyna, 1973).

The dominant management problems identified by Smith & Michalyna (1973) are maintaining adequate surface drainage and adequate fertility whilst preventing the erosion of organic matter-rich surface by wind. Construction of road and drainage ditches since settlement has greatly improved drainage (Smith, & Michalyna, 1973).

Soil Study

Site selection.

The fields selected for the study of shelterbelts' effects on soil biological activity were chosen based on their typical representation of local fields and shelterbelts type, as well as their similarity in soil properties, field and shelterbelt design, management type and history. Shelterbelts in the area are generally single rows of mixed Manitoba Maple, Green Ash and Caragana in the age bracket of 25-50 years old (Indian Head Agricultural Research Foundation, 2000). Shelterbelts' orientation can either be East-West or North-South, with the later offering a stronger barrier to wind in winter (Kort, 1988). The productions mostly associated with shelterbelts are potatoes, combined with a rotation of wheat, canola and corn (Indian Head Agricultural Research Foundation, 2000).

Four sites were selected for the study, including two sheltered fields and two non-sheltered fields. All four sites were located within a 10km radius with as similar soil and shelterbelt characteristics, agricultural practices and cropping history as possible (Appendix B-Removed). Detailed soil survey maps of the area of Morden and Winkler provided by Manitoba Agriculture, Food and Rural Initiatives (MAFRI) indicated that the dominant soil is Gleyed Rego Black from medium to moderately fine texture in Site 1, 2
and 3 and moderately coarse to coarse textured in Site 4. The fields' owners and managers indicated that they were cropped since at least the 1970s, with the main production being potato, corn, wheat and canola. The 2012 annual crop was canola. None of the fields have tile drainage, nor did they receive manure in the past 7 years. The shelterbelts are single tree rows, North-South orientated, aged 25-30 years old, with an approximate height of 15m and width of 7-8 meters. The vegetation structure consists of a thick grass cover and a homogenous under story of Caragana (Caragana arborescens) and top story of Green Ash (Fraxinus pennsylvanica). The field size varied between 97ha and 60ha.

**Site characteristics.**

Site 1 and Site 2 were both sheltered fields managed by different farm enterprises. Both sites had a similar averaged electrical conductivity at 0.5m depth of 23mS/m but Site 1 was richer in humus and organic matter content. Site 1 was a 60ha field located in a highly sheltered area. Site 2 was part of a 97ha field located in a lesser sheltered area.

Site 3 and site 4 were non-sheltered fields, both managed by the same farm enterprise as Site 2. Site 3 was part of the same field as Site 2 with similar soil type and management history. The Site 3 average electrical conductivity at 0.5m depth was lower than that of Site 4 (14 mS/m versus 19.8 mS/m). Additionally soil organic matter was also lower in Site 3 compared to Site 4.

**Sampling dates and conditions.**

The effect of shelterbelts on soil biological activity and soil fertility was studied using microbial biomass carbon, earthworms, organic matter content and mineralised organic nitrogen. The sampling was conducted over one week in September 2012 after harvest (Brussaard, De Ruiter, & Brown, 2007). All fields were lightly tilled before the
samples were collected. Sampling was re-conducted in May 2013 for earthworms only, prior to any soil work being conducted (Clapperton, 2004). The weather conditions in September 2012 were clear and dry, with an average temperature of 13 °C and 45% air humidity. Soil humidity was low, between 4.3% and 13% depending on the sites and soil temperature ranged between 14 °C and 21 °C. In May 2013 the soil moisture ranged between 22 and 32% and soil temperature between 12 °C and 15 °C.

**Sampling plot design.**

Each study plot consisted of four East-West transects of 60m, located 30m apart from each other (M. Entz, personal communication, August 25, 2012). Four sampling points per transect were taken, including the central part of the shelterbelt and in adjacent fields at 5m, 25m and 60m from the shelterbelt’s edge (Appendix C) (H. Sandhu & J. Huising, personal communication, June 12, 2012). In the case of non-shelterbelt sites, the sampling points followed the same design except for the shelterbelt point being within the field. This design was selected to determine the effect of shelterbelts on adjacent fields' soil biological activity and soil fertility compared to non-sheltered fields, as well as to provide an indication of changes in soil biological properties with distance from shelterbelts (E. Barrios, personal communication, May 15, 2012). The soil was sampled on the eastern side of the shelterbelt and at a minimum distance of 130m from any other landscape element such as road sides, ditches or other shelterbelts. The 130m distance was chosen following the measurement of the ground electrical conductivity (EM38) in millisiemens per meter (mS/m) at 0.5m and 1m depth, which indicated a relative homogeneity in salinity levels across transects past 130m from landscape elements, especially roadside ditches. The transect orientation is on the leeward side of the
shelterbelt (Eastern side) because it is the one protected from the dominant wind (Kort, 1988)

**Soil data collection and analysis.**

The soil environmental conditions such as salinity, temperature and moisture were collected instantly using a wet sensor type WET-2 from Delta T Devices Ltd. At every sampling point, two measurements were taken directly from a depth of 10cm (S. Sager, personal communication, September 6, 2012). Each measurement was averaged for a better representation of the environmental soil condition.

Earthworms were collected from 25cm² pits of soil in September 2012 and May 2013. The soil was sifted directly in the field using three separated layers of sifting sheets from coarse to small. Earthworms were identified visually and counted (H. Sandhu, & J. Huising, personal communication, June 12, 2012).

Microbial biomass carbon (MBC) was sampled from the top 7-8cm using a soil core of 100cm³ in volume from a bulk density kit. At each point, three samples were combined and mixed together (Anderson, 2003). Prior to each sampling, the recently tilled ground was lightly swept, removing the coarse residues of canola from the surface. The samples were stored at 4 °C and processed 40 days later in November 2012 at the Soil Science laboratory of the University of Manitoba (Ross, Tate, Cairns, & Meyrick, 1980). MBC was obtained using the University of Manitoba standard operating procedure of Chloroform Fumigation Direct Extraction (M.Tenuta, personal communication, August 15, 2012) (Appendix D). Prior to being processed, the samples were sieved to remove coarse residue and roots from the soil. MBC was originally measured in mg/kg, and
converted in g/cm$^3$ for the statistical analysis in order to align the variation in MBC with
the soil bulk density unit (Sparling et al., 1997).

Bulk density was sampled using the bulk density kit in a similar manner to MBC, but with only one core per point. The samples were stored in a freezer and processed in February 2013 at the Soil Science laboratory of the University of Manitoba. Bulk Density Determination was obtained using the University of Manitoba’s standard procedure by core method (M. Tenuta, personal communication, August 15, 2012) (Appendix D).

Organic carbon and organic nitrogen were sampled using a dutch auger of 2.5cm diameter at three layers (0-20cm, 20-40cm and 40-60cm) per point (Andrews, Karlen, & Cambardella, 2004). The samples were stored in a freezer and sent to Farmers' Edge laboratory to be analyzed in December 2012. Prior to sending, the samples were dried, sifted and grounded at the University of Manitoba. Due to budget limitations, 96 out of 192 organic nitrogen samples were analyzed, consisting of the shelterbelt point and the 60m in field point (M.Tenuta, personal communication, August 15, 2012). Organic matter content was determined by loss-on-ignition method and organic nitrogen was determined by automated distillation method. Both measures were taken from the same samples and expressed in percentage of dry soil.

Social Study

History and particularity of the Rural Municipality of Stanley.

The Rural Municipality (R.M.) of Stanley was selected as a result of a search for possible study sites across the prairies. Based on consultations with the Agroforestry Development Center based in Indian Head, SK, the University of Manitoba and the
Stanley Soil Management Association it was decided that the R.M. of Stanley was the most suitable location for research on shelterbelts.

The R.M of Stanley is located in the “Western Reserve”, an area granted to Russian Mennonites in 1873. This was the first major European settlement created without direct access to surface water or woodland (Smith & Michalyna, 1973). The settlers had experience on the Eastern European steppes and they successfully transformed the harsh prairie environment into a productive agricultural community. Mennonites farmers established a pattern of small villages such as Altona, Chortitz and Reinfeld and introduced a system of strip farming (Swyripa, 2010). Most farmers have now moved away from strip farming and adapted the quarter sections or multiples of quarters from individual farmsteads. The practice of shelterbelts for farmyard and field protection has however been maintained (Smith & Michalyna, 1973).

**Participative research.**

A participative approach to natural resources management is being increasingly adopted because of the need to develop knowledge and skills within rural communities to support the adoption of conservation practices and their maintenance for the long-term (Curtis & Lefroy, 2010). The direct cooperation of practitioners and community organisations with the researcher enhances stakeholders’ receptiveness to the project. Additionally their cooperation helps the researcher identify the most pertinent study design to successfully conduct the research. Community participation also contributes to reducing the gap between science and practice, potentially raising landholders’ awareness, and improving knowledge and management skills (Curtis & Lefroy, 2010).
Research project stakeholders.

The people involved in managing the agro-landscape are identified in this research as “stakeholders”. A total of eight stakeholders were identified and integrated into this project (Appendix E), with each having distinct objectives, values and perspectives regarding shelterbelt management. Stakeholders with a strong conservation interest included Pembina Valley Conservation District and Stanley Soil Management Association. Stakeholders with a production focus included farm enterprises and Agriculture Agri-Food Canada. Other stakeholders represented the public benefit and regulatory aspect of natural resources management such as the Rural Municipality of Stanley.

Stakeholder's participation and consultation.

Prior to the study design, individual and group meetings were organized to consult with stakeholders about the local farming community characteristics, standard farm operation and design, as well as shelterbelt types. The stakeholders' input helped determining the set of criteria needed to select a standard field and shelterbelt type. Each stakeholder was also asked to express their goals and expectations from participating in the research. Throughout the research project, stakeholders facilitated the development of the study by providing information, equipment and financial resources. Communication and community outreach were also important aspect of stakeholders’ participation, supporting public presentations and media releases about the research project.
Community survey design.

In November 2012, an exploratory questionnaire was presented to five of the participating stakeholders in order to identify the main themes of interest regarding the role of shelterbelts in the RM of Stanley and test preliminary questions (Appendix F). The information collected helped determining a pertinent theme and style of questions for the community survey (Barclay, Todd, Finlay, Grande, & Wyatt, 2002).

Following the exploratory questions review, a first draft of the survey was tested by five participants selected by the Stanley Soil Management Association to represent different community profiles in terms of age, education, culture and occupation. Based on the respondents’ comments, the survey design and wording were revised (Barclay et al., 2002).

A literature review about farming community surveys indicates that a 30% or lower response rate is common (Mauro et al., 2009). Statistical significance from quantitative survey was estimated to be viable from a minimum of 30 completed surveys (Krejcie & Morgan, 1970). Setting a target of 90 completed surveys, and taking into account an expected 30% response rate I therefore determined a total of 300 surveys would need to be sent out. The surveyed population deliberately included both farm operators and non-farmers in an effort to capture differences in opinions regarding environmental amenities from two key valuation perspectives; (1) those who live in rural landscapes and are responsible for land use decisions (farm operators), and (2) those who live in rural landscapes but do not actively make such decisions (non-farmers) (Grala, 2012). Residential profiles were identified using the R.M of Stanley water utility map and registry book based on population density between acreages, residential villages and
town. I then randomly selected 300 participants shared between 100 identified farmers, and an equal 66 residents from acreages, residential villages and townships.

Each pack contained a survey cover letter, head letter from the R.M of Stanley, a brochure about shelterbelts, the survey and a stamped self-addressed return envelope to the R.M of Stanley (Appendix G). The survey was sent out in the first week of January 2013. The survey was advertised in local newspapers, the municipal newsletter and its website during the second week of January. A second press statement was released in the third week to the local newspapers, as well as follow up phone calls to 100 randomly selected participants to encourage participation (Barclay et al., 2002). The surveys were collected from the R.M. of Stanley office in February, a month after their release. By then 162 surveys had been returned, 103 were completed and 59 were blank, which gave a 34.3% return rate.

**Survey content**

The survey consisted of eight types of questions including demographic, open ended multiple textbox on shelterbelt local knowledge, a Venn’s diagram on connectedness, semantic differential scale on shelterbelts’ benefits, multiple choice on shelterbelt perceived benefiting category, rank order scaling on influential local actor, contingent valuation (CV) for willingness to pay and open ended questions for open comments.

Demographic questions aimed at determining the socio-cultural profile of respondents and identifying possible demographic influences regarding the perception and values of shelterbelt. Cultural forces incite individuals to feel incorporated into bonded units (e.g., community group) and to abide by externally imposed rules such as
norms or practices. Traditions or religious beliefs are particularly strong cultural forces that can greatly influence the sense of connectedness to nature (Dutcher et al., 2007). The demographic parameters that were used to identify cultural forces regarding shelterbelt values were age, cultural affiliation, occupation, residential type and origin of knowledge about shelterbelts. The age categories 18-25, 26-50 and 51 or older were chosen to express the influence of experience based knowledge related to different weather cycles; bearing in mind the last significant dry cycle that occurred in the R.M of Stanley was in 1985, 28 years ago. Residential type aimed at evaluating the influence of proximity to nature as a living environment with regards to shelterbelt values. Cultural affiliation aimed at defining values linked with cultural bias. Origin of knowledge between family, community and farming practitioners provides an indication of the influential cultural forces regarding shelterbelts.

Local knowledge of shelterbelts was determined from respondents’ citation of 5 perceived functions, and three perceived risks from shelterbelts and perceived losses associated with their removal. Local knowledge of farmers and farming community members is experience-based and represents a reliable source of information (Mauro et al., 2009). Farmers and community have a holistic knowledge of agro-ecosystems and the socio-cultural factors embedded in rural communities. Additionally, attitudes towards risk incorporate socioeconomic, cultural, political, and agroecological factors can contribute to contrasts with expert science based knowledge (Mauro et al., 2009). It is especially useful in identifying the possible barriers and incentives to adoption of shelterbelt use. On the other hand the perceived risks associated with the removal of shelterbelts indicate the potential pressures that maintain shelterbelts within the system. Finally, the identification
of the most recognised functions or types of functions attributed to shelterbelts can indicate the strength and homogeneity of local knowledge, preferred functions and values regarding shelterbelts among the community (Kulshreshtha et al., 2003).

The Venn diagram provided an indication of connectedness to shelterbelts. Respondents’ positions reflected a spectrum of psycho-social and cultural perceptions ranging from complete separation to total integration of shelterbelts from their culture (Kumar, 2008). The aim of this question was to determine the extent to which respondents experience a sense of connectivity and closeness to shelterbelts within their self-representation and identity (Dutcher et al., 2007). A follow up question investigated the origin of connectedness between family, community and farming practitioners as an indication of the influence of peers in building local knowledge and values regarding shelterbelts.

Respondents’ preferred functions were determined by asking respondents to scale the importance of eleven given shelterbelt's functions between 1 and 10, 1 being the lowest and 10 the highest. The list of 11 shelterbelt functions was selected from Prairie Farm Rehabilitation Administration literature on shelterbelt’s functions and benefits (Kulshreshtha & Kort, 2009). In addition, respondents were asked to associate the given functions with a choice of three beneficiaries including community well-being, ecosystem conservation and agriculture productivity. This question was designed to reveal individual preferences among shelterbelts’ ecosystem services. The utility that an individual derives from a given ecosystem service will influence its decision-making when faced with trade-offs among competing functions (Kumar, 2008).
Respondents’ willingness to pay was measured using the contingent valuation method. Two hypothetical scenarios of service demand were created for respondents to express shelterbelts’ services in monetary ways (Farber, Costanza, & Wilson, 2002). Evaluating the broader community’s willingness to pay to support multi-functional agro-landscape can help farmers and related managers in their decisions regarding shelterbelts’ value and management (Dosskey et al., 2012).

Finally, the preferred management body for shelterbelts was identified using a rank order scale. Open-ended textboxes were provided after each section of the survey to allow respondents to expand and share their opinions. The open comments provide qualitative, in-depth information about particular topics, also indicating the community preferred topics and level of awareness on some issues (Mauro et al., 2009).

**Ethical review**

An ethical review of the study was conducted according to the Royal Roads University (RRU) *Ethic Policy for Research Involving Humans* (2011) and was approved by the RRU Research Ethic Board in July 2012. The requirements of the ethical review included the provision of a letter of invitation and consent to all people surveyed or interviewed for the thesis research. It was explained to all participants during interviews or in the survey that any participation is voluntary and can therefore be declined. The information provided is anonymous and owned by the researcher only. Information provided could be withdrawn prior to publication of the thesis if the participant wished. Finally a copy of the thesis research would be made available to the participating community through the Municipality library database or upon request.
Statistical Analysis

Soil biology study.

The effects of shelterbelt treatment on soil properties was statistically analysed across three distances (5m, 25m and 60m) using an analysis of variance (ANOVA) and a correlation analysis from the Statistical Analysis Software (SAS). In this case, the shelterbelt points were excluded, and the field points were all combined to compare the mean of sheltered versus non sheltered field soil properties. Earthworms and organic nitrogen could not be analysed with ANOVA due to a lack of normality and missing data.

The correlation analysis aimed at identifying connection between soil biological, chemical and environmental properties. No conclusion regarding cause-effect relationships was made from the correlation analysis due to the small scale of the study and low number of replicates. Based on the differences in least mean square, we identified the points that were significantly different to others (P<0.05). The Kolmogorv-Smirnov Test for Normality (>0.1500) was used because of the small sample size of the study.

Social study.

Two surveys were designed and sent to three hundred randomly selected participants. One survey named "A" was answered by 55 respondents, while the second survey "B" was answered by 47 respondents. The quantitative and qualitative information collected was entered into a spreadsheet and organised according to a self-made coding system (R. Gulden, personal communication, March 22, 2013. The data took the form of ordinal measurements (highest number is attributed the highest value) or nominal measurements (elements are assigned to qualitative categories). Descriptive statistics
including frequency distribution, median, mean and sum were used to determine the
general surveyed population demographic, values and knowledge on shelterbelts. The
correlation procedure from Statistical Analysis Software was used to identify
relationships between, with and by variables based on the level of significance $P<0.05$
and the Pearson Correlation Coefficient $r >0.047$ (R. Gulden, personal communication,
March 22, 2013).
The effect of Shelterbelts on Soil Biological Activity, Fertility and Environmental Conditions

Soil biological and fertility indicators.

Microbial biomass carbon (MBC) and earthworms population were measured along 60m transects and statistically compared using an analysis of variance from 2 sets of sheltered and non-sheltered fields. While replicate one did not show significant differences in MBC between sheltered and non-sheltered soil, replicate two’s MBC showed significant differences between treatment (P<0.0001), being higher in the field adjacent to the shelterbelt (0.14mg/cm$^3$ of dry soil in average) compared to the non-sheltered field (0.08mg/cm$^3$ of dry soil) (Figure 1).

MBC was twice as high within the shelterbelts compared to the averaged adjacent cultivated soil with 0.30mg/cm$^3$ versus 0.14mg/cm$^3$. MBC varied with distance from the shelterbelt in a non-significant manner, gradually decreasing between 5m and 25m but increasing again at 60m (Figure 1). In both sites, the highest MBC within the field was found at the 60m sample point from the shelterbelt (Figure 1).
Earthworms were sampled in September 2012 and again in May 2013. Both times they were found only in Site 1, with a higher population in May (89 in total) than in October (45 in total). Earthworms were found mostly in shelterbelts (41/45 in September 2012 and 73/89 in May 2013). The number of earthworms found in the adjacent fields decreased with distance from shelterbelt and had zero earthworms at 60m within the fields. Their numbers within the fields slightly increased in May 2013 compared to September 2012, but were overall very low with less than 15 earthworms compared to the 73 in the shelterbelt soil.

Soil fertility was measured based on organic matter content (OM) and organic nitrogen; both were sampled at 0-20cm, 20-40cm and 40-60cm depths. OM was significantly different (P<0.05) between sheltered and non-sheltered fields at all depths, being higher adjacent to shelterbelt compared to non-sheltered fields. In replicate two, OM at 0-20cm represented 1.5% of dry soil in non-sheltered field compared to 2.1%
adjacent to a shelterbelt. At 20-40cm, non-sheltered field OM was 1% of dry soil compared to 1.7% adjacent to a shelterbelt. The 40-60cm depth showed the strongest difference with OM being twice as high in the sheltered area than in non-sheltered area (1.15 % compared to 0.7%). Organic Matter did not change significantly due to distance from shelterbelts, being slightly higher in the shelterbelt (2.30%) compared to the averaged cultivated soil (2.07%) (Figure 2).

![Organic Carbon 0-20cm (%)](image)

**Figure 2.** Organic Carbon in percentage of dry soil by treatment at four distances, R. M. of Stanley (2012). Level of significance follows P<0.05*, P<0.01 ** and P<0.001***. Treatment includes SF-Avr= Sheltered field average, C= Non-sheltered field. Distance includes SHT=Shelterbelt, 5 metres, 25meters and 60metres.

Organic nitrogen (ON) was higher in the sheltered field compared to the non-sheltered field. At 0-20cm depth, the sheltered soil counted 0.13% of ON, compared to 0.08% in a non-sheltered soil. At 20-40cm depth, ON reaches 0.1% in a sheltered soil versus 0.05% in a non-sheltered soil. At 40-60cm, a sheltered soil produces 0.05% ON, compared to 0.03% in a non-sheltered soil. No statistical analysis was conducted due to the lack of data from the sheltered field.
Soil environmental conditions

Soil environmental conditions including soil temperature, soil moisture and bulk density were surveyed at the same time of the data collection in September 2012. Ground electrical conductivity was surveyed prior to designating the plots in order to assess salinity homogeneity among transects.

All soil environmental conditions significantly varied by treatment except for bulk density. In September 2012, soil adjacent to the shelterbelt had lower temperature and higher moisture and ground conductivity (Table 1). Soil environmental conditions also varied with distance from the shelterbelts with soil moisture, soil temperature, ground conductivity and bulk density being lower in the shelterbelt compared to the adjacent field (Appendix J).

Table 1. Analysis of variance of soil environmental variables, R.M. of Stanley, September 2012.

<table>
<thead>
<tr>
<th>Replicate 2</th>
<th>Soil temperature (Degree Celsius)</th>
<th>Soil moisture (%)</th>
<th>EM38-05m (mS/m)</th>
<th>EM38-10m (mS/m)</th>
<th>Bulk density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-sheltered</td>
<td>20.9844 (0.29)</td>
<td>4.3625 (0.36)</td>
<td>14 (0.81)</td>
<td>22.25 (1)</td>
<td>1.40063 (0.03)</td>
</tr>
<tr>
<td>sheltered</td>
<td>17.8417 (0.44)</td>
<td>8.90833 (1.74)</td>
<td>22.4167 (1.59)</td>
<td>31.0833 (1.41)</td>
<td>1.4475 (0.03)</td>
</tr>
<tr>
<td>ANOVA</td>
<td>&lt;.0001***</td>
<td>0.0185*</td>
<td>0.0095**</td>
<td>0.0056**</td>
<td>0.3531n.s</td>
</tr>
<tr>
<td>Degree of Freedom</td>
<td>11</td>
<td>11</td>
<td>11</td>
<td>11</td>
<td>11</td>
</tr>
</tbody>
</table>

Note: The table shows the mean and the standard error in bracket. Treatments include sheltered and non-sheltered field. Level of significance follows P>0.05n.s., P<0.05*, P<0.01 ** and P<0.001***.

Correlation analysis between soil biological, chemical and environmental properties.

A correlation analysis was conducted to test the strength of relationship between MBC, OM at 20cm, organic nitrogen at 20cm and the other soil environmental
parameters. In sheltered fields, we found that Site 1 MBC was positively correlated to OM at all depths, with the strongest correlation being the 20-40 cm layer (r=0.7). OM was positively correlated to ground conductivity (r=0.6) and ON (r=0.9). ON was positively connected to OM at all depths, but strongest at 40-60 cm depth (r=0.95), and negatively correlated to ground conductivity (r=-0.9) and bulk density (r=-0.7) (Appendix L).

Site 2 did not show similar correlation patterns. MBC is not significantly correlated to OM or ON. It was however positively correlated to soil moisture (r=0.7) and negatively correlated to soil temperature (r=-0.6). OM was significantly correlated to bulk density (r=0.8) (Appendix L).

The Significance of Shelterbelts Cultural Services to the R.M of Stanley Community

Survey demography.

The population surveyed was predominantly Male (92%). The majority of respondents were older than 51 years (57.8%) while the rest were between the ages of 26 and 50 years (42.2%). The great majority of respondents were born in Canada (87.3%), lived on acreages (73.5%), were farmers (64.7%) and felt a strong connection to farming (63%). Self-identified cultural groups included Mennonites (27.5%), Canadians (26.5%), followed by Farming Culture (10.8%) and European (7.8%). Twenty two percent of respondents did not answer the question about cultural affiliations and were therefore labelled as “no culture” (Appendix I).

Shelterbelts' importance and level of connectedness to the community.

All respondents were asked to rate the importance of shelterbelt to the R.M of Stanley Municipality on a scale of 1 to 10, 1 being the lowest and 10 the highest. Shelterbelts were given 10/10 importance by 23% of respondents, 8/10 importance by
27% of respondents and 7/10 importance by 10% of respondents. Overall, 72% of respondents rated the importance of shelterbelts 7 or higher (Figure 3).

By profile, shelterbelts were rated the highest by Farming Culture with 7.5/10 compared to other cultural groups (Table 5). By occupation, non-farmers rated shelterbelt importance to the municipality the highest (7.8/10 versus 6.9/10).

Figure 3. Shelterbelts importance to the municipality on a scale of 10, N=103, R.M. of Stanley (2013). This figure shows the percentage of respondents that rated shelterbelts' importance from 1 (minimum) to 10 (maximum).

Respondents of Survey B were asked to scale their level of connectivity with shelterbelts as an individual, as a community member and as a professional using a Venn Diagram, and indicate the origin of their connectedness. At an individual level, most respondents felt strongly connected to shelterbelts (64%), the remainder felt partially connected (34%) as no respondents expressed a low individual connection. As a community member, 43% of respondents expressed a high connection to shelterbelts, 38% felt partially connected while 17% felt no connection. As a professional, 43% of
respondents indicated a high connection to shelterbelt, 30% expressed a partial connection while 24% felt they had had no connection (Figure 4).

![Sense of Connectedness to Shelterbelt](image)

*Figure 4. Connectedness to shelterbelt from an individual, community and professional perspective, N=47, R.M. of Stanley (2013). This figure represents the degree of connectivity felt by respondents with shelterbelts from high, medium to low.*

While being generally high, connectedness to shelterbelts differed among respondents. Canadians expressed the highest individual connection (66.7%), while Farming Culture expressed the highest community and professional connection (Both being 60%) to shelterbelts. By occupation, Farmers expressed a higher individual connection than non-farmers but had a similar community connectedness. Respondents living on acreages expressed the highest individual connection to shelterbelts, while town and village residents expressed a higher community connection to shelterbelts. The biggest variation in individual connection came from respondents who received their knowledge of shelterbelts from practitioner peers (71.4%), compared to community-based knowledge (42.9%) (Appendix K). The origin of connectedness to shelterbelt predominantly came from family peers (55%), followed by practitioner (30%) and community peers (13%).
Community preferred functions and perceived beneficiaries.

Respondents were given a list of 11 shelterbelt functions and asked to scale each function's importance out of 10, 1 being the lowest and 10 being the highest. The functions included (1) air purification (dust, chemical drift & odors), (2) biodiversity (wildlife, plants, pollinators), (3) climate regulation (temperature, moisture, wind speed, carbon sequestration), (4) cultural heritage (property landmark, community identity, tourism attraction), (5) quality of life (health, comfort, aesthetics), (6) resilience of agro-landscape to disturbances, (7) scientific discoveries (potential new cures or food sources), (8) traffic related impacts (snow management), (9) soil protection, (10) timber production (construction and biomass fuels), and (11) water cycling and purification. Respondents were then asked to associate each function to their perceived predominant benefiting category between community well-being, ecosystem conservation, and agriculture productivity.

The functions rated the highest were climate regulation, agro-ecosystem resilience and soil protection, scoring respectively 7.2, 7.4 and 8.7 out of 10. The functions rated the lowest were cultural heritage, scientific discoveries and timber production, scoring respectively 5.6, 4.7 and 4.6 out of 10. The remaining functions were scaled between 6.4 and 7 out of 10, including biodiversity (7.1), quality of life (7), traffic related impacts (7), air purification (7) and water cycling and purification (6.4).

Shelterbelt functions were perceived to predominantly serve community well-being. Indeed, 64% of all functions were associated to community well being. It included the functions of cultural heritage, life quality, traffic related management, air purification, water cycling, scientific discoveries, and timber production (Figure 5). Agriculture
productivity was related to soil protection, climate regulation and agro-ecosystem resilience representing 27% of all functions. Biodiversity conservation was the only function associated to ecosystem conservation as the predominant beneficiary. This information provides an indication of the perceived beneficiaries of shelterbelts. Since community well-being was the main benefiting category of shelterbelts' functions, we can therefore associate shelterbelts as a significant source of public benefits.

![Figure 5](image)

*Figure 5.* Shelterbelts' preferred functions and perceived beneficiaries, N=55, R.M of Stanley (2013). This figure shows the average rank given to each function of shelterbelts. Each category is associated to one beneficiary between community well-being, agriculture productivity and ecosystem conservation.
The importance attributed to shelterbelt functions varied greatly, and seemed to be linked to the perceived beneficiary. Functions that primarily served agriculture productivity received the highest scores such as “soil protection”, “climate regulation”, and “agro-ecosystem resilience”. On the other hand, functions associated with community well-being received some of the lowest scores including “air purification”, “water cycling”, “scientific discoveries” and “timber Production” (Figure 5). On average, functions associated with community well-being were rated the lowest (6/10), compared to ecosystem conservation (7/10), and agriculture productivity which received the highest rate (7.8/10). We therefore conclude that shelterbelts may provide mostly social benefits, but they are primarily valued for the services to agriculture.

Opinions regarding the beneficiaries of shelterbelt functions varied greatly among respondents. The difference in strength of association can be an indication of the degree of consensus or disparity among respondents’ values regarding shelterbelts. Overall, functions that gained the greatest consensuses were soil conservation (75% agriculture),
cultural heritage (73% community), quality of life (72% community) and traffic related impacts (61% Community). Functions that were predominantly associated to one beneficiary were scientific discoveries (54% Community), climate regulation (53% Agriculture), agro-landscape resilience (51% Agriculture) and biodiversity (48% Ecosystem). Functions that had the lowest consensus were air purification (40% Community), water cycling and purification (38% Community) and timber production (37% Community) (Appendix K). The weak association to one particular benefiting category might indicate that these functions strongly interrelate between Agriculture Productivity, Ecosystem Services and Community Well-Being.

**Community local knowledge of shelterbelts’ functions.**

The community local knowledge about shelterbelt functions helped determine the level of recognition and significance of shelterbelt socio-cultural functions. The shelterbelt functions provided by the respondents were categorized in order to represent the spectrum of functions between environmental, economic and social benefits. A total of 30 functions were registered and classified among six categories including environment, ag-environment, agriculture, socio-economic, socio-environment and socio-cultural (Table 2).

Each respondent provided an average of four functions. The function most recognised was “protection of soil”, mentioned by 40 out of 47 respondents. The three other most recognised functions were “snow catch” (30), “aesthetics (23), and “habitat for wildlife” (21) (Table 2). Most shelterbelt functions cited related to the ag-environment category (38.6%), which alters the environment for agriculture benefits. The second category of functions most cited was social-environment (22%), which was associated to
the modification of the environment to improve health and living conditions. The socio-cultural category represented 15.3% of all functions cited. The environment category made 14.8% of all functions cited. The last categories were agriculture representing only 5.8%, and socio-economic with 3.7% of all functions cited (Figure 7).

Each category counted different numbers of functions, indicating the diversity of benefits received within each category. The socio-environmental category was comprised of the most functions, with 9 identified services, followed by ag-environment (5) and agriculture (5). Categories that counted the least functions were socio-economic (4), environment (3) and socio-cultural (3) (Table 2). The local knowledge of shelterbelts was concentrated to a few functions mainly relating to tempering weather extremes and protecting assets for agriculture benefits. Some functions were cited more than others, indicating various levels of consensus and shared knowledge within the community about shelterbelt’s most important functions. Local knowledge related to ag-environment was highly focused on soil protection and snow trapping, representing 40 and 30 responses respectively out of 73 functions. Local knowledge related to socio-environment was more equally distributed. The most mentioned function was wind reduction, with 16 out of 42 functions. The socio-cultural category primarily consisted of the aesthetic function (23/29) (Table 2).
Table 2. Community local knowledge of shelterbelt organised by socio-economic and environmental functions, N=47, R.M of Stanley (2013)

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Functions (Dominant)</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environment</td>
<td>Conservation, non-utilitarian / intrinsic values</td>
<td>• Pollinators&lt;br&gt;• improve ecosystem&lt;br&gt;• habitat for wildlife (21)</td>
<td>28</td>
</tr>
<tr>
<td>Ag-Environment</td>
<td>Modify environment for agriculture benefit, utilitarian indirect function</td>
<td>• protect soil (40)&lt;br&gt;• reduce salinity&lt;br&gt;• snow management (30)&lt;br&gt;• moisture&lt;br&gt;• attract rain</td>
<td>73</td>
</tr>
<tr>
<td>Agriculture</td>
<td>Direct benefit to Agriculture by increasing or preventing a decrease of productivity</td>
<td>• heat units (6)&lt;br&gt;• increase crop yield&lt;br&gt;• reduce evapotranspiration&lt;br&gt;• prevent crop damage&lt;br&gt;• livestock shelter</td>
<td>11</td>
</tr>
<tr>
<td>Eco-social</td>
<td>By product with an economic or social gain</td>
<td>• reduce energy bill&lt;br&gt;• wood energy&lt;br&gt;• pesticide segregation&lt;br&gt;• employment</td>
<td>7</td>
</tr>
<tr>
<td>Social-Environment</td>
<td>Modify environment to improve living conditions and well-being. Protect from environmental hazard – utilitarian</td>
<td>• sound control&lt;br&gt;• air quality&lt;br&gt;• dust control (6)&lt;br&gt;• oxygen&lt;br&gt;• reduce wind (16)&lt;br&gt;• safety from weather&lt;br&gt;• moderate climate&lt;br&gt;• shade&lt;br&gt;• yard shelter (11)</td>
<td>42</td>
</tr>
<tr>
<td>Socio-cultural</td>
<td>Influence cultural asset, landscape structure and identity</td>
<td>• aesthetic (23)&lt;br&gt;• field boundaries&lt;br&gt;• privacy</td>
<td>29</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>6</td>
<td>30</td>
</tr>
</tbody>
</table>
Figure 7. Category of shelterbelt functions cited by the community as important, N=47, R.M of Stanley (2013).

**Community perceived risks from shelterbelts’ removal.**

The perceived risks associated with shelterbelt’s removal help determine whether the removal of shelterbelts is associated with loss of socio-cultural capital. Respondents identified an average of two risks which were allocated to six different categories including cultural, environment, socio-environment, socio-economic, agriculture and ag-economic (Table 3).

The risks associated with shelterbelt removal by frequency were "wind", mentioned 38 out of 47 respondents, "bird habitat" (8), "snow management" (8), "lack of shelter" (6) and "bad aesthetic" (6) (Table 5). The socio-environmental category was the most mentioned, representing 46.5% of all identified risks. Increased wind was the most mentioned risks within the socio-environmental category (Figure 8). The second most recognised category was ag-economic with 17.8% of all risks mentioned relating to the
direct cost and physical impact of removing shelterbelts (Figure 8). The most mentioned type of risk within this category was that of tree stumps left in fields (5/18) (Table 3).

The category which counted the most type of risks was ag-economic (7), followed by environment (6), socio-environment (4), agriculture (4), culture (3) and socio-economic categories the least amount of risks (2). (Table 3)
Table 3. Perceived risks associated with the removal of shelterbelts, N=47, R.M. of Stanley (2013)

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Risks (Dominant)</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultural</td>
<td>Visual impair</td>
<td>• bad aesthetic (6)</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• border dispute</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• driving conditions</td>
<td></td>
</tr>
<tr>
<td>Environment</td>
<td>Conservation, non-utilitarian / intrinsic values</td>
<td>• ground water recharge</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• air quality</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• ecosystem function</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• less air moisture</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• pollination</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• bird habitat (8)</td>
<td></td>
</tr>
<tr>
<td>Socio-Environment</td>
<td>Improve living conditions and well-being. Protect from hazards – utilitarian</td>
<td>• Wind (38)</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• lack of shelter</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• environ benefit</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• drought</td>
<td></td>
</tr>
<tr>
<td>Socio-economic</td>
<td>By product that serve a socio-eco gain</td>
<td>• spray drift</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• energy cost</td>
<td></td>
</tr>
<tr>
<td>Agriculture</td>
<td>Directly benefit agriculture by increasing or preventing a decrease of productivity</td>
<td>• snow moisture (8)</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• less heat unit</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• reduce crop yield</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• wind damage</td>
<td></td>
</tr>
<tr>
<td>Ag-economic</td>
<td>Direct cost and disturbance from shelterbelts’ removal</td>
<td>• Cost</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• re-planting</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• physical work</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• burning shelterbelt</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Stumps removal (5)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Waste</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Unlevel ground</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6</td>
<td>26</td>
<td>101</td>
</tr>
</tbody>
</table>
Figure 8. Perceived risks associated with the removal of shelterbelts, N=47, R.M. of Stanley (2013). This figure shows the percentage each category of risk represents according to the community.

Community perceived risks from shelterbelts.

The community perceived risks associated with shelterbelts helped identify the potential barriers to shelterbelt practices and conservation. From a list of two risks on average provided by the respondents, a total of five categories were created including ag-environment, direct costs, indirect costs, ag-design and socio-cultural (Table 4).

The risks that were most recognised by respondents were the “need for renovation” and “interference with equipment”, both were mentioned 14 times overall (Table 4). The most recognised risks from shelterbelts related to the ag-environment category (42%). Commonly cited environmental interferences with crop production included "scattered branches" (11/40), "weeds" (9/40) and "snow excess" (8/40). The ag-design category was the second most recognized category of risk, representing 30% of all risks mentioned. It focused mainly on "interference with equipment" (14/31). The indirect
cost category represented 19% of all risks mentioned, mainly concerning "renovation needs" (14/20) (Table 4 and Figure 9).

The category that gathered the most risks was ag-environment, with 10 identified issues, followed by ag-design with 5 issues. The direct cost, indirect cost and socio-cultural categories counted less than three types of risk each (Table 4). This is a good indication that respondents perceived risks from shelterbelts were largely focused on interferences with agriculture production and operations.

The analysis of perceived risks by profile indicated that Mennonites expressed significantly higher indirect cost related risks than others, representing 26.5% of all risks mentioned compared to 18.8%, 16%, and 12.5% for No Culture, Canadians and Farming Culture respectively. The ag-environment related risks are mentioned the most by No Culture, comprising 56.3% of all cited risks, while all other cultural groups perceived about 40% of ag-environment related risks. The ag-design related risks were most recognised by Farming Culture (50%) and Canadian (40%) compared to Mennonite (23.5%) and No Culture (12.5%). Little difference was observed between farmers and non-farmers appreciation of ag-environment and ag-design related risks.

The socio-cultural category of risks mainly referred to bad aesthetics. The profile that particularly expressed socio-cultural risks were Non-farmers (10%) versus farmers (2.4%), which is an indication of the rural communities expectations and pressure on the farming community to maintain and renovate shelterbelts for the public benefit. Among cultural groups, No Culture were the one mentioning the most socio-cultural risks (6.3%), followed by Canadians (4%). Neither Farming Culture nor Mennonites mentioned any cultural risks.
Table 4. Perceived risks from shelterbelts, N=47, R.M. of Stanley (2013)

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Perceived risk (Dominant)</th>
<th>Frequency</th>
</tr>
</thead>
</table>
| Ag-Environment    | Indirectly interfere with productivity due negative ecological interactions with production | • absorb fertilizer  
• poor field efficiency  
• take moisture from crops  
• snow accumulation (8)  
• ridge building  
• disease from high humidity  
• scattered branches (11)  
• pest  
• disease  
• weeds (9) | 44                     |
| Direct cost       | Direct associated cost                                                        | • cost  
• fencing for livestock                                                               | 5         |
| Indirect cost     | Indirect associated cost                                                      | • planning and preparation  
• renovation (14)                                                                   | 20        |
| Ag-design         | Direct impact on farming due to shelterbelts’ expansion and interference with equipment and barrier to field management | • encroachment  
• interfere with equipment (14)  
• take too much space  
• too close to each other  
• permanent field shape | 31                     |
| Socio-cultural    | Visual impair & safety hazards                                                 | • look bad when not maintained  
• visibility and intersection  
• environmental activist                                                            | 4         |
| Total             |                                                                               | 5  
22  
104 |
Perceived influential actors of shelterbelt practice.

The perceived influential actors of shelterbelt’s practice and conservation were determined. Respondents ranked seven actors from the highest (1) to the least (7) influential. Results indicated that municipal government, conservation organisation and provincial government were perceived as very influential by most respondents. On the other hand, agro-industry, Keystone ag-producer and federal government were perceived the least influential actors. Community groups were placed in the middle by most respondents (Appendix L).

Willingness to pay for shelterbelts benefits.

The respondents’ willingness to pay for shelterbelts was determined using contingent valuation based on an annual payment from $0 to $10 to maintain the benefits received from shelterbelts within the municipality. Some respondents did not complete the questions (24.5%) or expressed a zero willingness to pay for shelterbelts’ services (25.5%). Fifty percent of the respondents did however indicate a willingness to pay for
shelterbelts. Twenty-two percent of the respondents offered to pay between $1 and $9 per year, eighteen percent agreed on $10 per year while ten percent offered $11 or more (Figure 10).

![Figure 10. Willingness to pay an annual payment between $0 and $10 to maintain the benefits received from shelterbelts in the municipality, N=102, R.M. of Stanley (2013). This figure shows the percentage of respondents willing to pay an annual fee from $0 to $10 towards shelterbelts' maintenance within the R.M of Stanley.](image)

**Relationships between respondents' profile and shelterbelts’ socio-cultural values.**

Early on observations of the social and cultural values for shelterbelts among respondents showed that variations mainly occurred within “cultural affiliation” and “occupation” classes. The study of shelterbelts’ social and cultural values by profile was therefore primarily focused on these two influential socio-demographic characteristics.

**Social values for shelterbelts.**

Mennonites associated the most functions with community well-being (78%), while Canadians associated the least community well-being as the predominant
beneficiary of shelterbelts ‘functions (45%) (Table 5). On the other hand, Canadians cited significantly (>0.0392) more socio-environmental services as important functions of shelterbelts than other cultural groups (29.4% versus 21%), while Farming Culture expressed the fewest (15%) (Table 5). The rate given to functions associated with community well-being was particularly high among Farming Culture (6.8). Canadians on the other hand rated shelterbelt functions related to community well-being low (5.8). Finally, Mennonites expressed the most social-environmental risks (56.5%) from shelterbelt removal.

By occupation, Non-farmers appreciation for socio-environmental services was higher than farmers. Non-farmers associated a greater number of functions with community well-being (72%) than farmers did (50%). Farmers also valued community well-being functions lower (5.8) than non-Farmers (6.5) (Table 6).

**Cultural values for shelterbelts.**

The appreciation and recognition of shelterbelts’ cultural functions were generally low compared to other types of functions. Respondents with no affiliated culture identified the most cultural services (25%) as part of shelterbelts’ functions and expressed the most cultural risks with shelterbelt removal (17%) whilst Mennonites cited the least cultural functions (8.7%) and Farming Culture expressed the least cultural concerns with the removal of shelterbelts (Table 5). On the other hand Farming Culture rated shelterbelts cultural heritage function significantly (P<0.03) higher than other groups (7.7/10 versus 5.3/10 in average).
Table 5. Shelterbelts social and cultural values by cultural affiliation.

<table>
<thead>
<tr>
<th>Cultural affiliation cross-tabbing</th>
<th>Mennonites (N=28)</th>
<th>Canadians (N=27)</th>
<th>Farming Culture (N=11)</th>
<th>No Response (N=23)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shelterbelts rate out of 10</td>
<td>7.3</td>
<td>6.8</td>
<td>7.5</td>
<td>7.1</td>
</tr>
<tr>
<td>Average rate of social functions out of 10</td>
<td>6.2</td>
<td>5.8</td>
<td>6.8</td>
<td>6.2</td>
</tr>
<tr>
<td>Average rate of Cultural Heritage out of 10</td>
<td>5.5</td>
<td>5.3</td>
<td>7.7</td>
<td>5.5</td>
</tr>
<tr>
<td>Share of functions serving community well-being</td>
<td>78%</td>
<td>45%</td>
<td>62.50%</td>
<td>62.50%</td>
</tr>
<tr>
<td>LK associated with social functions</td>
<td>21%</td>
<td>29.4%</td>
<td>15%</td>
<td>21%</td>
</tr>
<tr>
<td>LK associated with cultural functions</td>
<td>8.7%</td>
<td>16%</td>
<td>15%</td>
<td>25%</td>
</tr>
<tr>
<td>Share of social loss from shelterbelts' removal</td>
<td>56.5%</td>
<td>54%</td>
<td>45%</td>
<td>35%</td>
</tr>
<tr>
<td>Share of cultural loss from shelterbelts' removal</td>
<td>13%</td>
<td>12.5%</td>
<td>0%</td>
<td>17%</td>
</tr>
</tbody>
</table>

Table 6. Shelterbelts social and cultural values by occupation.

<table>
<thead>
<tr>
<th>Occupation cross-tabbing</th>
<th>Farmer (N=67)</th>
<th>Non-Farmer (N=35)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shelterbelts rate out of 10</td>
<td>6.9</td>
<td>7.8</td>
</tr>
<tr>
<td>Average rate of social functions out of 10</td>
<td>5.8</td>
<td>6.5</td>
</tr>
<tr>
<td>Average rate of Cultural Heritage out of 10</td>
<td>5.8</td>
<td>6.5</td>
</tr>
<tr>
<td>Share of functions serving community well-being</td>
<td>50%</td>
<td>72%</td>
</tr>
<tr>
<td>LK associated with social functions</td>
<td>19.70%</td>
<td>28.00%</td>
</tr>
<tr>
<td>LK associated with cultural functions</td>
<td>14.50%</td>
<td>17.00%</td>
</tr>
<tr>
<td>Share of social loss from shelterbelts' removal</td>
<td>45.00%</td>
<td>50.00%</td>
</tr>
<tr>
<td>Share of cultural loss from shelterbelts' removal</td>
<td>10.00%</td>
<td>12.50%</td>
</tr>
</tbody>
</table>
Bias and Limitations of the Study

Soil study.

Site selection.

The sheltered and non-sheltered sites were paired to analyse the effect of shelterbelt on soil biological activity and fertility. Site 1 was paired to Site 4 while Site 2 was paired to Site 3. The comparison between Sites 2 and 3 is particularly powerful as they are part of the same field, hence with similar soil properties and management history. The comparison between Sites 1 and 4 is weaker due to the difference in fields and the overall high sheltered area Site 4 is located in. As a consequence Sites 2 and 3 were used as the dominant replicate to discuss the treatment effect of shelterbelt on soil properties (Appendix B-Removed)

Sample size.

The study was designed to still achieve statistical significance while using the minimum sample size possible; due to time and resource restrictions. The sample size was determined based on degree of freedom which represent the minimum number of independent coordinates required to characterize the system (M.Tenuta, personal communication, August 15, 2012). A minimum of 12 data points was agreed to with the thesis supervisors.

Each study was replicated once. Each plot consisted of four transects, enabling the combination of four samples per point. Shelterbelt fields had a total of 12 points taken within the field and non-sheltered fields had a total of 16 points (Appendix C). The data collected from the replicate was not merged because of the genuine differences between sites, despite similar characteristics and history. Overall the sample size was small and
largely related to an observational study of shelterbelt effects on soil biological activity and soil fertility.

**Social Study.**

**Non-response bias.**

The survey was checked for non-response bias. Non-response bias is defined as the kind of bias that occurs when some subjects choose not to respond to particular questions and when the non-responders are different in some way (they are a non-random group) from those who do respond (Barclay et al., 2002). Specific measures were taken to encourage and simplify survey participation. It included a hand written and personalized cover letter signed by the R.M. of Stanley, a description of the research and instructions on how to complete the survey. The package contained a stamped self-addressed envelope to the R.M. of Stanley. The survey was designed to take less than ten minutes to complete with ready to fill questions and the provision of examples. An option to respond to the survey by phone or request assistance in case of language barriers was provided. Several reminders were advertised in the public press, municipality website and by phone about the surveys importance and due date, No financial remuneration however was offered (Barclay et al., 2002).

Despite the measures taken to avoid non-response bias, important prejudices were observed. Higher response rates were found from farmers and rural residents than non-farmers and urban residents, probably due to different levels of concern and knowledge on the topic of shelterbelts. Language and cultural barriers were found to also limit the participation of recent immigrants or those of ethno-religious groups who did not use English as their first language, or who did not wish to participate in public affairs. As a
result, the demographic profiles have an unequal pool of respondents. The low pool of respondents such as town residents (N=12) or farming culture (N=11) may not be as accurate and reliable for generalisation as the larger pool of respondents such as acreage residents (N=75) or farmers (N=67) (Appendix H).

An analysis of the respondents’ socio-demographic information showed significant relationships between some variables. Farmers were significantly related to acreage residents and to respondents that received their knowledge of shelterbelts from practitioner peers. Non-farmers on the other hand were correlated to village and town residents. Respondents that were in the 51 years old age group were significantly related to Canadians and town residents, while 26-50 years old were correlated to village residents and no culture.

Quantitative data coding

The social study had a number of biases and limitations to acknowledge in order to fully appreciate the results and implications. The identification of the functions beneficiary between community, ecosystem and agriculture was based on the category which was predominantly mentioned by respondents. The category might however not represent a majority (Appendix I). For example, 40% of respondents associated “Air” with community well-being, while 26% associated Air with ecosystem conservation, 23.8% with agriculture productivity and 9.5% with all benefits together. In this sense, we could say that community well-being was the main beneficiary, followed by ecosystem conservation and agriculture productivity. Some respondents rated the functions but did not indicate a beneficiary. Information was therefore missing from the general pole. Additionally, functions were sometimes associated to several beneficiaries. Such
information was removed as it would have been inaccurate to enter the function in one or the other benefiting category and nor should it be counted twice.

Another possible bias regarded the categorisation of the functions mentioned by respondents as presented in Table 2. The determination of each function purpose and bene...
showed limitations in consistency. The pool of respondents differed per profile and rarely showed significant correlations with respondents’ answers.
Discussion

**Effect of Shelterbelts on Soil biological Activity and Fertility**

This study of the effect of shelterbelts on soil biological activity and fertility provided some evidence that shelterbelts interact with the agro-landscape soil ecological functions and processes (Thevathasan & Gordon, 2004), producing beneficial supporting ecosystem services for soil formation and fertility (Barrios, 2007).

Soil biological activity and soil biophysical properties were significantly influenced by the presence of shelterbelts in a similar manner according to Wojewoda & Russel’s (2003) study. Microbial biomass carbon (MBC) and earthworms were both higher within the shelterbelts compared to cultivated fields. MBC was two times higher within the shelterbelts compared to the adjacent cultivated soil while 91% of earthworms were sampled in the shelterbelt. These results provide some evidence that belowground biodiversity is influenced by above ground biodiversity (Lavelle, 1997) and shelterbelts play a role of refuge for belowground biodiversity, providing a reservoir of soil organisms within an intensively cultivated landscape (Bird, 1999).

Soil biological activity was significantly higher in fields adjacent to shelterbelts compared to non-sheltered fields. No earthworms were found in non-sheltered fields. We found that earthworm displayed a highly clustered population. Whalen (2004) suggested that earthworms’ irregular and aggregated distribution may be related to vegetation, soil characteristics and biotic interactions (Whalen, 2004).

Soil fertility indicators were also significantly higher in sheltered fields compared to non-sheltered. Organic matter and organic nitrogen were both higher in sheltered fields than non-sheltered fields. The higher level of organic matter might be due to leaf residue
and effective topsoil protection from wind erosion (Wojewoda & Russel, 2003). These results give some indication that shelterbelts favour the maintenance of soil organisms and their functioning as regulators of nutrient cycling. Shelterbelts therefore contribute to soil health and fertility (Wojewoda & Russel, 2003).

Soil environmental conditions were significantly different between sheltered and non-sheltered fields. Indeed, fields adjacent to shelterbelts had tempered soil temperature and soil moisture levels compared to non-sheltered fields. The correlation analysis indicated significant different relationships between MBC and the microclimate produced by shelterbelts as well as with organic matter content. Site 1 resulted in significant positive correlation between MBC and OM, with the strongest correlation being with OM at 20-40cm depth. Organic nitrogen was also positively correlated to OM. Site 2 resulted in positive correlation between MBC and soil moisture and negative correlation with soil temperature. The environmental and biophysical properties of the soil adjacent to the shelterbelt might therefore provide a favourable habitat and promote soil biological activity (Altieri, 1999). Soil biological activity is a critical component of organic matter decomposition, nutrient cycling and availability; such as nitrogen mineralization (Lavelle, 1997). As a consequence soil health and fertility adjacent to shelterbelts is improved (Giller et al., 1997).

**Agro-landscape Biodiversity Conservation and Soil Health**

Our findings indicate that shelterbelts as a landscape practice can contribute to agriculture resilience by enhancing biodiversity and soil health. The maintenance of permanent bio-geographical features like permanent vegetation structure at the landscape scale can optimize the ecological services and synergies beneficial to agriculture
production while reducing the tradeoffs between production and conservation, which is critical for the conservation of biodiversity and ensuring long term agricultural soil health (Lavelle, 1997). Our results are consistent with Kort (1986) and Wojewoda & Russel’s (2003) studies which demonstrated that shelterbelts facilitated a microclimate, contributed to soil organic matter and produced a favorable effect on microbial biomass carbon in adjacent fields.

**Link between Shelterbelt Practice and Prairie Community Well-being**

The surveyed community of the Rural Municipality of Stanley expressed a rich appreciation for shelterbelts far beyond the single function of soil protection and production values for agriculture. Community well-being was perceived as the predominant beneficiary of shelterbelts, compared to agriculture and ecosystem conservation. Respondents identified a wide variety of social services provided by shelterbelts with a total of nine different important functions compared to five for agriculture. Additionally, the removal of shelterbelts raised a majority of social concerns. These results comply with the study conducted by Kulshreshtha & Kort (2009) which identified many valuable public services obtained thanks to the prairie shelterbelts program.

The community well-being functions were given a wide range on the scale of importance, from very high to very low. For example, shelterbelts were highly valued for contributing to quality of life and traffic, which might indicate that they have been purposely planted to improve living and traffic conditions. On the other hand they were not highly valued for contributing to cultural heritage or scientific discoveries despite primarily serving community well-being. Those functions may not be targeted ones, and
therefore the benefits received are not valued. Such external benefits could be defined as the free riders of soil conservation practices. Good soil management is linked to soil health which in turn provides broader societal, environmental and economic benefits and services. The most tangible examples of public benefits obtained from soil conservation are clean water and air quality (Bennett, Mele, Annett, & Kasel, 2010). It is therefore interesting that water and air purification functions of shelterbelts were rated low and only weakly associated to community well-being by respondents. It might indicate that the community have a low awareness on the effect shelterbelts have on air and water purification and cycling and how those ecological services contribute to their own resource provisions.

The socio-cultural value of shelterbelts appeared very strongly based on connectedness, but poorly valued and recognised by participants. Reduction of the landscape aesthetic, lack of shelter and protection from the environmental hazards were important perceived socio-cultural risks. There was however no mention of sense of place, cultural heritage or identity as perceived risks of shelterbelt removal. Non-productive functions such as sense of place or family heritage are intangible and relate to cognitive knowledge. Such emotional or spiritual values are often predominant in traditional societies (Burel, 1996). Prairie communities however may have not developed or explicitly formulated such cognitive connection to their land and environment. By cultural affiliation, farming culture rated cultural heritage functions significantly higher than other cultural groups. It might indicate that shelterbelts are valuable to farmers to structure the landscape and characterise the farming and rural community identity. It was surprising however that farmers and acreage residents rated cultural heritage quite low at
5.3 out of 10. Respondents not affiliated to any culture cited the most cultural functions and perceived the greatest cultural loss in relation to shelterbelt removal. On the other hand Mennonites cited the least cultural functions, while farming culture did not express any cultural loss related to the removal of shelterbelts. This is interesting because “No culture” could be considered one end of the cultural spectrum compared to Mennonite and Farming Culture. The fact that “No Culture” expresses a high recognition of shelterbelt’s cultural services might indicate that they particularly rely on the landscape structure to develop their community identity and sense of place. On the other hand, well-connected residents in a tight-community such as Mennonites may not distinguish their community assets from one another because of their level of familiarity with the environment.

Interestingly, respondents seemed to either associate shelterbelts with a high proportion of socio-environmental services or with cultural services, but rarely both. For example, village residents identified many social services, and few cultural services. On the other hand, town residents mentioned fewer social-environmental services and more cultural services. Overall cultural risks were not highly recognised and accounted for only three types of risk. Concerns seemed to be on a more practical scale, with mundane issues such as border disputes or driving conditions, rather than spiritual or cognitive services (Busck, 2002).

Connectedness to shelterbelts was however significant to the whole community. Farmers as well as non-farmers expressed strong emotional bonds to shelterbelts associated to family heritage. Most respondents felt a very high individual connection to shelterbelts (63.8%), placing shelterbelts as a component of their individual identity.
Community connectedness was shared between high and medium, indicating that respondents’ community identity is relatively affiliated to shelterbelts. Professional connectedness was either high or low. Shelterbelts, which are often described as an agricultural tool, related therefore more to respondents’ self and community identities rather than their professional identity.

The majority of respondents gained their knowledge and appreciation of shelterbelts from family peers. Knowledge gained through family is a strong driver of conservation, as it becomes inherent to the socio-cultural identity and norms of the person. To farmers, it often translates as conservation being integrated into the farm long term planning and daily practices (Kumar, 2008). The connection remains however within the private domain and the knowledge may vary greatly between families. Almost 30% of respondents felt that their connection to shelterbelts originated from practitioner peers. Connection gained from the professional environment is likely to build appreciation for shelterbelts as a conservation agricultural practice, with good recognition of the services provided as well as their limitations. Such knowledge is important as it may help justify the use of shelterbelts in agriculture in economic terms. Community peers as a source of connectedness to shelterbelts was low, which indicated that the subject of shelterbelts may not appear often within public discussion. Such source of communication and information can be very valuable in building education across all socio-demographic profiles, fostering a vision and set of values to sustainably manage a common landscape (Curtis & Lefroy, 2010).

We found however, that based on the scale of importance, shelterbelts’ preferred functions were agriculture productivity. Functions related to agriculture as a beneficiary
was constantly rated the highest. The majority of functions cited by respondents targeted soil protection and moisture management for agriculture benefits. These results demonstrate that the decision to plant shelterbelts is driven by practical and productive goals, based on identified utility (Busck, 2002). Shelterbelts are defined as soil conservation elements, and are therefore valued based on the few soil related indicators (Busck, 2002).

**Agriculture Barriers to Permanent Conservation Practices**

Despite a strong appreciation and recognition of their contribution to soil conservation and agro-system resilience, shelterbelt agricultural value is decreasing. The survey showed a large consensus about the importance of shelterbelts for soil protection from wind erosion and agro-ecosystem resilience which was rated the highest by most respondents. Numerous perceived risks associated to shelterbelts were however mentioned, generally linked to interference with crop production and farm operation. Competition with high priced agricultural land, and barriers to advanced technology such as tile drainage or GPS guidance were mentioned as important limitations to permanent conservation practices. The adoption of minimum or no tillage was also mentioned as an effective replacement of shelterbelts’ protective function against soil erosion. To farmers, it is not economically legitimate to maintain a permanent conservation practice, for the single purpose of topsoil protection especially when severe winds are occasional and infrequent (PFRA, 2000).

Additionally, respondents identified many negative ecological interactions between shelterbelts and adjacent fields, such as competition for moisture and nutrients, as well as weed and pests issues. Such issues are the result of dysfunctional shelterbelts.
Scientific studies have proven since the early 20th century that shelterbelts can contribute to crop productivity if they are well designed and functional (Kort, 1986). Managing shelterbelts spatially and temporally to optimise the beneficial ecological interactions and synergies with production goals is a complex practice which require regular maintenance (Thevathasan & Gordon, 2004). Respondents experiencing disfunctional shelterbelts might under-estimate the complexity of shelterbelt practices and lack the skills or knowledge to optimise their design and management. More assistance is required with training and providing information about effective shelterbelt design, plantation, maintenance and restoration plan. Such information campaigns might help reduce landowners’ perceptions that shelterbelts are prejudicial to agriculture and therefore encourage their adoption and conservation. Similarly, the mention of indirect costs as the third most important type of risk indicated that planning and management requirements are limiting factors to landholders. This could either be helped by contracting external services, organising cooperative maintenance of shelterbelts or by improving landholders knowledge on shelterbelt self-management, in order to make it more efficient and less time-consuming.

The perception of risks related to the removal of shelterbelts showed a low appreciation of opportunity costs for agriculture productivity. Despite the acknowledgement that shelterbelts provided important services to agriculture, the biggest perceived impact of shelterbelt removal related to the community socio-cultural well-being. The second biggest type of risk from removing shelterbelts related to the direct physical and technical cost of removing shelterbelts. Surprisingly, there were little negative perceived risks to agriculture production. Respondents were more concerned
about the effort required to remove shelterbelts rather than loss of ag-services and benefits. It demonstrates that farmers may not feel the need to maintain shelterbelts for productive purposes, but experience strong psychological barriers to removing them (Kumar, 2008). Most farmers have planted their shelterbelts on their own, requiring long hours of physical work for planting and care. The personal effort they have invested in establishing the shelterbelts might weigh heavily in their appreciation and decision making regarding shelterbelts conservation (Busck, 2002).

A number of risks were expressed regarding ecosystem conservation, mainly regarding birds. Few potential issues related to ecosystem functions and processes were mentioned, which might be an indicator that shelterbelt are not considered as an ecological element of the agro-ecosystems.

**Decision Making Regarding Shelterbelt Practice**

There are powerful drivers of shelterbelt practices and values. Education is a key to conservation practices. Soil protection for example was very highly rated by all respondents and especially by 26-50 year olds compared to those 51 years and older. This might be an indication that in the last 20 years there has been an effective educational campaign about the importance of soil conservation and the role shelterbelts can play (Kort, 1988). The educational campaign might be more influential to farmers’ values and decision-making than personal life experiences are. On the other hand, it is surprising that the ecosystem conservation was perceived as the last beneficiary of shelterbelts and counted for only three types of functions. It might indicate low community knowledge or appreciation of shelterbelt’s contribution to ecosystem conservation. Shelterbelts are a landscape element that supports many ecological functions, processes and interactions
vital to the agro-ecosystem resilience and sustainability. It includes below and above ground biodiversity habitat, biological connectivity across the agro-landscape, pollination, water regulation and filtration, organic matter decomposition, carbon cycle and sequestration. The Southern Manitoba agro-landscape is an intensively managed environment with very little remnants of natural areas and processes. The rural community might perceive the agricultural landscape and the ecosystem as two separated entities. They therefore do not perceive shelterbelts as being an element of an ecosystem, only a productive land. By better understanding shelterbelts as an ecological element of the landscape, farmers could better exploit the ecosystem services which are beneficial to agriculture, while minimizing competition with crop production. Education about the value of shelterbelts for ecosystem conservation and how it is linked to broader societal, environmental and agriculture outcomes is therefore necessary (Bennett et al., 2010).

Cultural practices also greatly influenced shelterbelt values. Mennonites appeared to associate shelterbelts the most with social values rather the economic or environmental ones. They also expressed the highest social loss from shelterbelt removal. The R.M of Stanley, a predominantly Mennonite settlement, has maintained a high density of shelterbelts within its farming system. Conservation of shelterbelt practices might be linked to Mennonites’ strong relation to traditional farming values (Swyripa, 2010). Landscape practices are often integrated to holistic and long term farm planning. Decisions regarding such practice are highly related to the sense of responsibility and stewardship for the landscape health (Busck, 2002). Interestingly, Mennonites mentioned the highest number of risks and perceived the most indirect cost of all cultural profiles. It might indicate that Mennonites are particualrly involved in shelterbelt plantation and
maintenance as part of their daily farm operations, and are therefore more aware than
other cultural groups about the related issues of time and labour. Such resentment might
also indicate a need for greater support in terms of knowledge, equipment and skills.
Interestingly, other profiles likely to have a strong experience of shelterbelt management
did not necessarily mention high indirect costs such as acreage or farming culture. The
profile of the community can therefore influence the type of involvement and
participation in conservation work (Curtis & Lefroy, 2010). Highly connected and well
rooted communities might perceive conservation as part of their farming lifestyle.
Environmental and community stewardship responsibilities are closely interrelated to the
holistic vision of farming. Less established and rooted communities may have a stronger
recognition of each component of the system, and therefore respond more strongly to
targeted conservation programs. Such cultural shifts and change of attitude towards
landscape practices are clearly visible during change of land ownership. Shelterbelts are
particularly prone to removal when new landowners establish themselves (PFRA, 2000).

Environmental and community stewardship constitute strong drivers of shelterbelt
conservation. The changes in agriculture and associated tradeoffs that farmers are
experiencing are however strong pressures and can represent a barrier to their
conservation. It is therefore important to verbalise the significance of shelterbelts for the
rural community well-being. If the removal of shelterbelts as a landscape element is
undesirable to the public, then farmers should have incentives to maintain or replace them
(Bennett et al., 2010). Shelterbelts are widely perceived as privately owned and managed.
The broad recognition of shelterbelts contribution to the public living environment, well-
being and health, shows however that non-farmers may have a role to play in their
conservation. Farmers and Non-Famers perceive shelterbelts differently. Farmers for example associated quality of life and agro-ecosystem resilience to agriculture whereas non-farmers related these same functions with community well-being. Public health and well-being can therefore be effective drivers of shelterbelt conservation, raising questions about the legitimacy of considering shelterbelts as a private asset rather than a public one (Kulshreshtha & Kort, 2009). The implications this provides for the plantation, management and maintenance of shelterbelts is considerable, as it would mean that costs could be shared among all beneficiaries, which is to say the rural community, and not just landholders. Examples of incentives might be payments or rewards based on voluntary schemes for services provided by shelterbelts to identified beneficiaries such as public roads or specific land use such as waterway protection. Ultimately, higher recognition and understanding from the rural population about farmers’ contribution to public benefits can greatly increase peer support for shelterbelt practices.

Half of the population expressed a willingness to pay for shelterbelts and twenty five percent did not answer the question. Explanation for not completing the question included lack of understanding of the questions, the incapacity to evaluate and provide a monetary value for shelterbelts’ services, or refusal to express a value of shelterbelts in monetary terms. Some respondents also argued that shelterbelts were located on private land and as a consequence should be the responsibility of the landowner only. The Municipal authority was considered the most influential actor regarding shelterbelts, possibly leading to community led natural resource management.
Conclusion and Recommendations

This research provided some evidence that shelterbelts are a significant element of the agro-landscape sustainability in the R.M of Stanley, Manitoba. It was found that shelterbelts provided production, conservation and livelihood benefits, strengthening the prairie agro-system resilience and community adaptive capacity to climate change.

Our first research question investigated the effects of shelterbelts on soil biological activity and fertility. We found that fields adjacent to a shelterbelt had higher microbial biomass and earthworms than non-sheltered fields, potentially due to the enhanced organic matter and soil micro-climate created by shelterbelts. Additionally, soil below shelterbelts contained significantly more micro-organisms than cultivated soil, thus acting as a precious reservoir for belowground biodiversity in an intensively cultivated landscape.

Belowground biodiversity is a critical vector of supporting ecosystem services such as soil formation and nutrient cycling, generally contributing to soil health and resilience (Giller et al., 1997). The positive effect of shelterbelts on soil organisms offers agriculture the opportunity to design farming systems in manners that enhance the ecosystem’s natural capacity to sustain soil formation and fertility, hence crop production.

The present study should be considered preliminary. However, further research can build on the findings of this study to increase our understanding of the spatial and temporal interactions of shelterbelts and soil biological activity and the potential for biologically fixed nutrients. Based on the positive indicators from this study, it is concluded that further research would be warranted.
Our second research question explored the social and cultural values of shelterbelts to the R.M. of Stanley community. We found that the predominant beneficiary of shelterbelts was community well-being, rating well above agriculture. Community well-being was also perceived to be most severely impacted by the removal of shelterbelts compared to agriculture productivity and ecosystem conservation. Such perceptions were particularly strong within Mennonite respondents.

The survey indicated that citizens of the R.M of Stanley feel strong cultural bonds to shelterbelts, associated to self-identity and family practice. Cultural significance of shelterbelts was however poorly verbalised with very few cultural functions purposely cited beyond landscape aesthetics. We found that the Farming Culture highly valued the cultural heritage functions of shelterbelts. On the other hand respondents who were not affiliated with a specific culture associated shelterbelts the most with cultural functions. We conclude that shelterbelts can play a significant role to some community groups in structuring the landscape and defining a community identity.

Despite community being presented as the main beneficiary of shelterbelts, socio-cultural benefits appeared to be free riders of private conservation agriculture. Shelterbelts’ preferred utility was agricultural productivity. Knowledge about shelterbelts mainly originated from family peers, and was strongly focused on soil protection and snow catch. We found that non-farmers also greatly valued shelterbelts for agriculture and community, but did not associate them with public affairs. The majority of respondents indicated a generally low willingness to pay for the public benefits of shelterbelts, rather maintaining it as a privately owned element of the landscape.
The community expressed strong resentment regarding shelterbelts interference with farm operations, lessening their agricultural value. In addition, the lack of recognition of shelterbelts’ social and ecological functions within the agro-landscape appeared to lead to a low opportunity cost of removing them. Based on the findings of this study, we conclude that shelterbelts provide significant cultural ecosystem services to the citizens of the Rural Municipality of Stanley. As a landscape practice and a guardian of soil health, shelterbelts provide many societal, environmental and economic benefits to the whole community.

Based on the research findings, several recommendations were developed to promote shelterbelt conservation. The conservation of shelterbelts may depend on the farming community’s capacity to recognise and verbalise the significance of the public social and ecological services they receive, while designing and maintaining shelterbelts in such ways that enhance ecosystem services to agriculture.

The holistic culture of farming plays a critical role in maintaining healthy production systems. Shelterbelts as a landscape practice are important elements of the socio-ecological system. The emotional and cultural forces that drive farmers’ decision making are powerful drivers of agricultural conservation that need to be better appreciated by agro-industries and agriculture programs. In the absence of such holistic management of the farming system however, it might be beneficial to enforce barriers to shelterbelt removal when they significantly benefit the socio-ecological system. Additionally, the redefinition of shelterbelts as a broader social and ecological contributor to the agro-landscape may provide farmers with further reasons to establish and conserve shelterbelts beyond only soil protection.
The conservation of shelterbelts is closely related to farmers’ stewardship values for their community and environment. Such values could be fostered by raising farmers’ awareness of shelterbelts social and ecological functions within agricultural systems. Community peer support and pressure can be effective tools to foster desirable behaviors including within landowners that may not have a strong family bond to the land. Encouraging community based knowledge and leadership regarding shelterbelt conservation could help develop a collective sense of stewardship of the land, thus enhancing partnerships between agro-landscape stakeholders to maintain and renovate shelterbelts. Additionally, investment in community and environmental stewardship can help reduce the gap between farmers and non-farmers by heightening the non-farmers appreciation of farming services for social cohesion and the well-being of the rural community as a whole.

Finally, since growing shelterbelts are a desirable practice for agro-system health, incentives should be implemented to encourage their conservation. It is important to remember that while shelterbelts may belong to private property, they become particularly effective as a network within the agro-landscape. Therefore quantification and mapping of shelterbelt’s ecosystem services at an agro-landscape scale may assist farmers in optimizing shelterbelt placement for private and public benefits. Additionally, the maintenance and renovation of shelterbelts are critical to ensure their long term multi-functionality; therefore access to training, technical equipment and shelterbelt by-product commercialization could represent effective incentives to farmers. Such cooperative platforms may already exist at the farm level but may benefit from expanding to an agro-
landscape scale with stakeholders such as municipal authority, conservation organizations and agricultural groups.
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Appendices

**Appendix A - Rural Municipality of Stanley location within Manitoba, Canada**

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The map represented the state of Manitoba borders within Canada with an indication of the study location.

Appendix B - Site location and design within the Rural Municipality of Stanley

This material has been removed because of copyright restrictions

The map represented the Rural Municipality of Stanley access roads and townships.

Reference: Manitoba transport and Government Services, 2003, The R.M of Stanley, Highway Planning and design branch, drafting section, Winnipeg
Appendix C - Example of plot design

Each plot was constituted of four sampling points along a 60m transect (within the shelterbelt, and 5m, 25m and 60m within the cultivated field) replicated three times. Each transect is located 30m apart. Non-sheltered plots have a similar design except for the shelterbelt sampling point being replaced by cultivated field. All plots were located a 130m away from other landscape elements such as road side, ditches and other shelterbelts.
Appendix D - University of Manitoba standard operating procedure for Bulk Density Determination and Microbial Biomass C&N Fumigation - Direct Extraction

**UNIVERSITY OF MANITOBA**

**Soil Ecology Standard Operating Procedure**

**Bulk Density Determination – Core Method**

**Equipment**
- aluminum soil cores
- trowel/shovel
- knife/spatula
- scale

**In the Field**
1. Record the number of core being used
2. Place insertion ring on top of core and press into soil with foot
   - if insertion ring is not available, another aluminum core can be substituted
3. Remove insertion ring
4. Use a trowel to extract core, keeping soil intact on both ends
5. Square ends with a knife or spatula, and place core contents in a plastic bag
6. Tie plastic bag and place in a cooler with ice packs

**In the Lab**
1. Weigh bag, core and soil and record mass in grams
2. Weigh several bags to determine an approximate mass per bag
3. Subtract mass of bag from mass of soil
4. Determine Gravimetric Moisture Content as per the GMC SOP

**Calculations**
- calculate mass of soil and core volume
  - mass of dry soil = (mass of full core – mass of empty core)/(1+GMC)
  - volume of core = πr²h
    - r = 2.54cm for all cores (diameter = 2")
    - h = length in data file (convert length to cm before entering it is the spreadsheet calculation)
  - BD = mass of oven dry soil (g)/volume of core (cm³)
Department of Soil Science Standard Operating Procedure

Microbial Biomass C & N – Fumigation-Direct Extraction

Equipment

- per soil sample:
- 2 square French bottles
- 2 #5 stoppers
- 2 Whatman No. 5 filter papers
- 4 30mL scintillation vials
- CHCl₃
- must be purified, dried, and distilled in glass
- must not be stabilised with ethanol. Hydrocarbon stabilised Caldon TN85-744
- boiling chips 4-5 boiling chips
- 100mL beaker
- Desiccator able to withstand a high vacuum without implosion
- Vacuum pump
- Fumehood
- 10% HCl acid bath
- 0.5 M K₂SO₄ solution
- 40-50mL CHCl₃

Procedure

Solutions
• Prepare 0.5 M K$_2$SO$_4$ solution by dissolving 87.135g K$_2$SO$_4$ crystals in 1L distilled water.

• Use moderate heat to help expediate the process.

**Soil**

• Weigh out two 25g portions of soil into the square French bottles.

• one sample will be fumigated for 24h and then extracted

• one sample will be extracted immediately

**Fumigation**

1. Prepare the desiccator for fumigation by lining it with moistened paper towels.

2. Place samples in desiccator with a 150mL beaker containing approximately 50mL of CHCl$_3$ and boiling chips.

3. Seal and evacuate the desiccator, taking care to vent the fumes released by the vacuum pump into the fumehood, until the CHCl$_3$ boils vigorously, and continue evacuating for approximately 2 minute.

4. Seal the desiccator under vacuum by turning collar, and leave for 24 hours.

5. After 24 hours, release the vacuum by turning the desiccator collar; a hissing noise should be heard. Remove the beaker of CHCl$_3$ and the paper towels.

6. Remove the residual CHCl$_3$ vapour from the soil samples by repeatedly evacuating the chamber 3 times for about 30 seconds each time.

**Extraction**

• Unfumigated samples are extracted immediately after weighing, while fumigated samples are extracted after 24 hours of fumigation.

1. Add 50mL of 0.5M K$_2$SO$_4$ to the square French bottles using a repipettor. Stopper the bottles using #5 stoppers. For each set of extractions, prepare two solution blanks containing only K$_2$SO$_4$.

2. Place the bottles on a lateral shaker set at high speed for 1 hour.

3. After shaking, pass the soil suspension through Whatman No. 5 filter paper.
- Funnels are not necessary; filter paper is folded and placed in the funnel rack directly.
- Filter paper should be rinsed with approximately 50mL deionised water prior to filtration.

4. Collect filtrate in 30mL scintillation vials.
- Two sets of filtrate samples are collected – A set and B set.
- Vials should be switched when the A vial is about 3/4 full.
- Vials should be labelled with the site name, original date of sampling, sample code, “F” or “U” for fumigated or unfumigated, and “A” or “B.”

5. Cap vials and placed in the freezer as soon as possible. The B set may be left overnight if the filtration time prolonged.

**Analysis**
- Analyse filtrate for N, C, NO$_3^-$, and NH$_4^+$ using the Technicon Auto-Analyser.

**Calculations**

1. Calculate the mass of C ($\mu$g g$^{-1}$ soil)

\[
= \frac{[ (\mu$g mL$^{-1}$ C)$_{\text{fumigated}} - (\mu$g mL$^{-1}$ C)$_{\text{blank}} ] \cdot [ \text{mL K}_2\text{SO}_4 + (\text{mass wet soil} \cdot \text{GMC}) ]}{(\text{mass of wet soil}/(1 + \text{GMC})}
\]

- $\mu$g mL$^{-1}$ C comes from the Auto-Analyser
- mass of wet soil/(1 + GMC) gives the mass of oven dry soil
- mass wet soil $\cdot$ GMC gives the mass of water in the sample

* to calculate the mass of C in the unfumigated sample, substitute the appropriate data value for ($\mu$g mL$^{-1}$ C)$_{\text{unfumigated}}$

2. Calculate the mass of microbial biomass C ($\mu$g C g$^{-1}$ soil)
\[ \text{CO}_2\text{C (fumigated)} - \text{CO}_2\text{C (unfumigated)} \]

\[
(0.25) \cdot \text{(mass dry soil)}
\]

* where 0.25 is a correction factor

* To calculate microbial biomass N, substitute the Auto-Analyser N data into the above steps, and use 0.18 as the correction factor in Step 2.

**Safety**

- All technicians are responsible for familiarising themselves with the Materials Safety Data Sheets for all chemicals used in this procedure.

- If WHMIS control products must be stored in containers other than their originals, a workplace label must be prepared for the new container. Control products include both pure decanted chemicals and prepared solutions.

**Notes**

- Square French bottles should be acid-washed for 24 hours, then rinsed with distilled water and allowed to dry prior to use.

- If more or less soil is used in the analysis, adjust the amount of \( \text{K}_2\text{SO}_4 \) added so that the ratio of soil:solution remains 1:2.

---

\(^1\text{Note: From “Microbial Biomass C&N Fumigation Direct Extraction,” and “Bulk Density Determination by Core Method” by M. Tenuta, Protocol of Soil Ecology Laboratory of the University of Manitoba Copyright 2014 by the Name of the M. Tenuta. Reprinted with permission} \)
Appendix E - List of the participating stakeholders in the research project

<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Level of participation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stanley Soil Management Association (SSMA)</td>
<td>Local not for profit Conservation Agriculture Organization</td>
</tr>
<tr>
<td>Pembina Valley Conservation District (PVCD)</td>
<td>Local not for profit Natural Resources Conservation Organization</td>
</tr>
<tr>
<td>R.M of Stanley</td>
<td>Municipal Authority</td>
</tr>
<tr>
<td>Manitoba Agriculture, Food and Rural Initiative (MAFRI)</td>
<td>Provincial Agricultural Government</td>
</tr>
<tr>
<td>Hespler Farms</td>
<td>Local Farm Enterprise</td>
</tr>
<tr>
<td>Haskett Growers</td>
<td>Local Farm Enterprise</td>
</tr>
<tr>
<td>Keystone Ag-Producers (KAP)</td>
<td>Provincial Farming Organization</td>
</tr>
<tr>
<td>University of Manitoba (UoM)</td>
<td>Natural System Agriculture Research team</td>
</tr>
<tr>
<td>Agriculture Agri-food Canada (AAFC)</td>
<td>Federal Agriculture Government</td>
</tr>
</tbody>
</table>
Appendix F - Exploratory survey addressed to the project stakeholders

The role of shelterbelts in the Stanley Municipality community sustainability

**Qualitative Question:** What socio-economic and environmental values does the rural community take into consideration when managing shelterbelts within their farming system? What social-economic and ecological benefits does the community get from shelterbelts?

**Qualitative Method:**

Exploratory meeting with key partners representative of the project stakeholders (Soil Management, Conservation District and Participating Farmer) to develop survey.

What does shelterbelt mean to you as a professional, a rural community member, a person?

What outcomes/information are you most interested in from the project?

How will this information be useful to you?

What do you think the community is going to be most interested in?

In the case of a survey, what question(s) would you like to ask to the community? Why

Which actors of the community would be most influential in establishing practices, norms, and enforcement of regulations regarding shelterbelt management?
Appendix G - Survey head letter and survey mailed to the community of the R.M of Stanley

Rural Municipality of Stanley

The Logo and contact details of the Municipality has been removed because of copyright restrictions.

Object: Social study on the community local knowledge, perceived benefits and willingness to pay for shelterbelts within the R.M of Stanley.

Included in this envelope are:

A survey

An informative brochure

A self-addressed stamped return envelope

Dear Sir (...)

General Information:

This 5 to 10 min survey is part of a graduate research project looking at the value of shelterbelts in the R.M of Stanley farming community.

The surveyed population deliberately includes both farm operators and non-farmers in an effort to capture differences in opinions regarding environmental amenities.

The results of the research will be accessible for public consultation September 2013.

The information collected from the survey is anonymous.

How to complete the survey:

By yourself or with your family you can complete and return this survey by January 30th 2013 to the R.M of Stanley office using the self-addressed stamped return envelope.

By phone: The contact details has been removed because of copyright restrictions.

If you do not wish to complete the survey, please return it to the R.M of Stanley office as it is using the self-addressed stamped return envelope.

Contact Information: For further information on the research project you can contact the researcher: The contact details has been removed because of copyright restrictions
Perceived Benefits and Community’s Willingness to pay for shelterbelts survey

Please return this survey by January 30th, 2013 to the R.M of Stanley office using the self-addressed stamped return envelope.

Definition: In this survey, shelterbelts refer to the rows of trees and shrubs planted in the farming landscape.

Section 1: Your socio-demographic information

Are you male or female?    Male    Female

Tick your corresponding age group:    18 – 25    26 – 50    51 or older

What is the highest level of education you have completed? _______________________

Tick the type of housing you currently live in:

    Acreage    Residential Village    Town

What is your cultural affiliation?

If you immigrated to Canada, what is your country of origin and when did you immigrate? Country of Origin: ______________________ Year of arrival in Canada: ______________________

If you are a farmer, what is your farming practice?

    Conventional    Conservation - No Till    Organic

What is your connection to farming?

    ☐ High, I have a direct connection to farming
    ☐ Medium, I have an indirect connection to farming
    ☐ Low, I have no connection to farming

Open comment:
Survey A Section 2: Scale the benefits you perceive from shelterbelts

Research shows that the perceived benefits of a person from nature are link to its preferences. These preferences greatly influence tradeoffs among different functions of nature and competing demands on available resources.

Instructions:

Rank between 1 (least) to 10 (most) the importance of the listed functions to you.

Rank which category benefits the most to the least from the function between agriculture productivity, ecosystem conservation and community well-being.

Example: The provision of shade: 1 2 3 4 5 6 7 8 9 10

<table>
<thead>
<tr>
<th>Agriculture productivity</th>
<th>Ecosystem conservation</th>
<th>Community well-being</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Interpretation: I think the provision of shade is somewhat important (average ranking) mostly for people well-being (protection from sun), then for animals and lastly for agriculture production.

1. Air purification (dust, chemical drift & odors): 1 2 3 4 5 6 7 8 9 10

<table>
<thead>
<tr>
<th>Agriculture productivity</th>
<th>Ecosystem conservation</th>
<th>Community well-being</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Biodiversity (wildlife, plants, pollinators): 1 2 3 4 5 6 7 8 9 10

<table>
<thead>
<tr>
<th>Agriculture productivity</th>
<th>Ecosystem conservation</th>
<th>Community well-being</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. Climate regulation (temperature, moisture, wind speed, carbon sequestration):

<table>
<thead>
<tr>
<th>Agriculture productivity</th>
<th>Ecosystem conservation</th>
<th>Community well-being</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. Cultural heritage (property landmark, community identity, tourism attraction):

<table>
<thead>
<tr>
<th>Agriculture productivity</th>
<th>Ecosystem conservation</th>
<th>Community well-being</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5. Quality of life (health, comfort, aesthetics): 1 2 3 4 5 6 7 8 9 10
Agriculture productivity ☐ Ecosystem conservation ☐ Community well-being ☐

6. Resilience of agro-landscape to disturbances (storms, droughts, floods, climate change): 1 2 3 4 5 6 7 8 9 10
Agriculture productivity ☐ Ecosystem conservation ☐ Community well-being ☐

7. Scientific discoveries (potential new cures or food sources): 1 2 3 4 5 6 7 8 9 10
Agriculture productivity ☐ Ecosystem conservation ☐ Community well-being ☐

8. Traffic related impacts (snow management): 1 2 3 4 5 6 7 8 9 10
Agriculture productivity ☐ Ecosystem conservation ☐ Community well-being ☐

9. Soil protection: 1 2 3 4 5 6 7 8 9 10
Agriculture productivity ☐ Ecosystem conservation ☐ Community well-being ☐

10. Timber production (construction and biomass fuels): 1 2 3 4 5 6 7 8 9 10
Agriculture productivity ☐ Ecosystem conservation ☐ Community well-being ☐

11. Water cycling and purification: 1 2 3 4 5 6 7 8 9 10
Agriculture productivity ☐ Ecosystem conservation ☐ Community well-being ☐

Open comments:
Survey B Section 2: Your local knowledge and connectedness to shelterbelts

Shelterbelts are part of farming landscapes in many parts of the world for various reasons.

List functions shelterbelts fulfill in your area from most important (1) to least important (5)?

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

The way people identify themselves in relation to their environment is a strong indicator of their ecological behavior and willingness to help nature.

In a scenario with your-self (light circle) and the entity shelterbelt (dark circle), scale your connection from “Highly connected” “Partially connected” “Not connected”

Example:

__________________________________________________________________________

Instructions: Draw a circle showing how important is shelterbelt to you as shown in the example above:

As an individual As a Stanley community member As a professional

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

Rank the most influential origin of your connectedness to shelterbelts?

Family heritage Community peers Agro-practitioners

Open comments:
The potential problems you associate with shelterbelts

Farmers and the community have a general knowledge of their environment. Attitudes toward risk include socioeconomic, cultural, political, and ecological factors that contribute to expert science based knowledge.

List the potential problems you associate with shelterbelts from most (1) to least (3) important:

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

List the potential problems you associate with the removal of shelterbelts from most (1) to least (3) important

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Open comments:

Section 3: Willingness to pay for shelterbelts’ perceived benefits

The services shelterbelts provide are generally not quantified and do not have a market value. Environmental economists have developed the concept of “Willingness To Pay” for the services received as an indication of market value.

On a scale 1 – 10, how important are the shelterbelts located in your municipality to you?

1 2 3 4 5 6 7 8 9 10

If you were to make a one-time payment for the benefits you receive from shelterbelts located in your municipality, how much would it be?

$_____
In the scenario that a collective fund was dedicated to maintaining shelterbelts for community benefits, how much would you be willing to pay per year for maintaining all shelterbelts located within the R.M of Stanley?

Circle your preferred value:  $ 1  2  3  4  5  6  7  8  9  10  Other __________

Rank the actors of the community you think is most (1) to least (7) influential in farmers’ decisions regarding the adoption or not of shelterbelts?

- Municipal government
- Provincial government
- Federal government
- Conservation organisations
- Community groups
- Agro-industry corporations
- Keystone Agricultural Producers

Please return this survey by January 30th, 2013 at the R.M of Stanley office using the self-addressed stamped return envelope.

Thank You for your time and contribution from the R.M of Stanley and the research team!
Appendix H - Survey socio-demographic information N=103, R.M of Stanley (2013)

<table>
<thead>
<tr>
<th>Category</th>
<th>Class</th>
<th>Population</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Male</td>
<td>93</td>
<td>92.1</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>8</td>
<td>7.9</td>
</tr>
<tr>
<td>Age</td>
<td>51 + yrs</td>
<td>59</td>
<td>57.8</td>
</tr>
<tr>
<td></td>
<td>26-50yrs</td>
<td>43</td>
<td>42.2</td>
</tr>
<tr>
<td>Education</td>
<td>University</td>
<td>20</td>
<td>19.6</td>
</tr>
<tr>
<td></td>
<td>Grade 12</td>
<td>50</td>
<td>49.0</td>
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<tr>
<td></td>
<td>Grade 9</td>
<td>7</td>
<td>6.9</td>
</tr>
<tr>
<td></td>
<td>Diploma</td>
<td>21</td>
<td>20.6</td>
</tr>
<tr>
<td></td>
<td>n/a</td>
<td>4</td>
<td>3.9</td>
</tr>
<tr>
<td>Housing</td>
<td>Acreage</td>
<td>75</td>
<td>73.5</td>
</tr>
<tr>
<td></td>
<td>Village</td>
<td>15</td>
<td>14.7</td>
</tr>
<tr>
<td></td>
<td>Town</td>
<td>12</td>
<td>11.8</td>
</tr>
<tr>
<td>Cultural affiliation</td>
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<td>27</td>
<td>26.5</td>
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<td></td>
<td>Mennonite</td>
<td>28</td>
<td>27.5</td>
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<tr>
<td></td>
<td>No answer</td>
<td>23</td>
<td>22.5</td>
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<tr>
<td></td>
<td>European</td>
<td>8</td>
<td>7.8</td>
</tr>
<tr>
<td></td>
<td>Farming</td>
<td>11</td>
<td>10.8</td>
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<tr>
<td></td>
<td>Others</td>
<td>5</td>
<td>4.9</td>
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<tr>
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<td>Canadian</td>
<td>89</td>
<td>87.3</td>
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<tr>
<td></td>
<td>Mexican</td>
<td>6</td>
<td>5.9</td>
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<td></td>
<td>South America</td>
<td>1</td>
<td>1.0</td>
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<td></td>
<td>Europe</td>
<td>6</td>
<td>5.9</td>
</tr>
<tr>
<td>Occupation</td>
<td>Farmer</td>
<td>Not farmer</td>
<td></td>
</tr>
<tr>
<td>-----------------------</td>
<td>--------</td>
<td>------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td>67</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td></td>
<td>65.7</td>
<td>34.3</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Farm practice</th>
<th>Conventional</th>
<th>Conservation</th>
<th>Organic</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>49</td>
<td>9</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>75.0</td>
<td>14.0</td>
<td>9.0</td>
<td>2.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Connection to farming</th>
<th>High</th>
<th>Medium</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>63.0</td>
<td>21.0</td>
<td>17.0</td>
</tr>
<tr>
<td></td>
<td>62.38</td>
<td>20.79</td>
<td>16.83</td>
</tr>
</tbody>
</table>
### Appendix I - Table of shelterbelts preferred functions and perceived beneficiary between social, agricultural and environmental outcomes

<table>
<thead>
<tr>
<th>Shelterbelt Functions</th>
<th>N</th>
<th>Rate of importance (10)</th>
<th>Predominant benefiting Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air purification</td>
<td>55</td>
<td>6.98182</td>
<td>40% Community well-being</td>
</tr>
<tr>
<td>Biodiversity conservation</td>
<td>55</td>
<td>7.09091</td>
<td>48% Ecosystem Conservation</td>
</tr>
<tr>
<td>Climate regulation</td>
<td>54</td>
<td>7.2037</td>
<td>53% Agriculture productivity</td>
</tr>
<tr>
<td>Cultural heritage</td>
<td>54</td>
<td>5.61111</td>
<td>73% Community well-being</td>
</tr>
<tr>
<td>Quality of life</td>
<td>54</td>
<td>7.01852</td>
<td>72% Community well-being</td>
</tr>
<tr>
<td>Agro-ecosystem resilience</td>
<td>54</td>
<td>7.40741</td>
<td>51% Agriculture productivity</td>
</tr>
<tr>
<td>Scientific discoveries</td>
<td>52</td>
<td>4.67308</td>
<td>54% Community well-being</td>
</tr>
<tr>
<td>Traffic related management</td>
<td>52</td>
<td>7.01923</td>
<td>61% Community well-being</td>
</tr>
<tr>
<td>Soil conservation</td>
<td>47</td>
<td>8.76596</td>
<td>75% Agriculture productivity</td>
</tr>
<tr>
<td>Timber production</td>
<td>54</td>
<td>4.62963</td>
<td>37% Community well-being</td>
</tr>
<tr>
<td>Water regulation and purification</td>
<td>54</td>
<td>6.42593</td>
<td>38% Community well-being</td>
</tr>
</tbody>
</table>
Appendix J – Soil environmental conditions

Figure 1a. Soil temperature (Degree Celsius) by treatment at four distances from shelterbelt

Figure 1b. Soil moisture (%) by treatment at four distances from shelterbelt

Figure 1c. Bulk density (g/cm$^3$) of dry soil by treatment at four distances from shelterbelt

Figure 1d. EM38 at 0.5m and 1m depth (mS/m) by treatment at four distances from shelterbelt
Appendix K - Correlation analysis of microbial biomass carbon (MBC), organic matter (OM) at 0-20cm and organic nitrogen (ON) at 20cm with soil biophysical variables

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Site 1</th>
<th>Site 2</th>
<th>Site 1</th>
<th>Site 2</th>
<th>Site 1</th>
<th>Site 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>MBC</td>
<td>r</td>
<td>0.967</td>
<td>0.926</td>
<td></td>
<td>0.808</td>
<td></td>
</tr>
<tr>
<td></td>
<td>p</td>
<td>0.000</td>
<td>0.000</td>
<td></td>
<td>0.015</td>
<td></td>
</tr>
<tr>
<td>Bulk density</td>
<td>r</td>
<td></td>
<td>0.815</td>
<td>-0.730</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>p</td>
<td></td>
<td>0.001</td>
<td>0.040</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OM20</td>
<td>r</td>
<td>0.698</td>
<td></td>
<td></td>
<td>0.919</td>
<td></td>
</tr>
<tr>
<td></td>
<td>p</td>
<td>0.012</td>
<td></td>
<td></td>
<td>0.001</td>
<td></td>
</tr>
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<td>OM40</td>
<td>r</td>
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<td>0.889</td>
<td>0.885</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>p</td>
<td>0.007</td>
<td>0.000</td>
<td>0.004</td>
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<td></td>
</tr>
<tr>
<td>OM60</td>
<td>r</td>
<td>0.570</td>
<td>0.937</td>
<td>0.948</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>p</td>
<td>0.051</td>
<td>&lt;.0001</td>
<td>0.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil Tp</td>
<td>r</td>
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<td>-0.617</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>p</td>
<td></td>
<td>0.033</td>
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<td></td>
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<td>Soil Moisture</td>
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<td></td>
<td></td>
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<tr>
<td></td>
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## Appendix L - Connectedness to shelterbelts by profile

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Appendix M - Ranking of management authorities from most to least influential regarding shelterbelt practice percentage (N=101), R.M of Stanley (2013)

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Appendix N - Correlation analysis of respondents’ socio-demographic parameters

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