COSTS, BENEFITS, AND BARRIERS TO THE ADOPTION AND RETENTION OF SHELTERBELTS IN PRAIRIE AGRICULTURE AS IDENTIFIED BY SASKATCHEWAN PRODUCERS

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By

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Abstract

The role of shelterbelts within prairie agriculture is changing. In the past, shelterbelts have been promoted and adopted for soil stabilization and their ability to protect farmsteads and livestock from harsh prairie climates. In today's agricultural landscape advances in production technology, an increase in farm size, and changes to policy have changed the circumstances in which decisions related to shelterbelts are made. The objective of this research is to identify the costs, benefits and the barriers to adoption and retention of shelterbelts that influence agricultural producers and landowners' management decisions related to shelterbelts in the Canadian Prairies. In the summer of 2013, surveys of producers and landowners from throughout the province of Saskatchewan (and several from Alberta) were conducted. Using the information collected in the surveys, the costs and benefits (both economic and non-economic), and potential barriers to adoption and retention of shelterbelts that influence producer's management decisions were identified and analyzed. This research identified that overall shelterbelts removal is increasing and that there are many barriers to adoption and retention for agricultural producers related to the economic costs. In addition, it was found that many of the benefits of shelterbelts are non-economic and more difficult for producers and landowners to recognize within their operations. Going forward, shelterbelts have the potential to play a major role in climate change mitigation by sequestering significant amounts of atmospheric carbon dioxide (CO_2) into the soil and as biomass carbon in aboveground and belowground parts of planted shelterbelt trees or shrubs within the agricultural landscape. In addition, shelterbelts provide many ecological goods and services to landowners and society. In conclusion, understanding the context in which producers are making decisions related to shelterbelts within their operations is important from an agricultural production, climate change, and policy perspective.

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Dedication

My thesis is dedicated to all of my family, and my friends who supported and encouraged me throughout my project. Special thanks to my husband (Roger Rempel), my parents (Mark and Susan Healey), my sisters (Nicole and Lisa), and my good friends (Astri Buchanan, Adele Lerner, and Heather Hallgrimson) who encouraged me and listened to me when I wanted to quit. Without all of your love and support this thesis would not have been possible.

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Chapter 1: Introduction

1.1 Overview

Shelterbelts are rows of planted or natural trees that are used chiefly to reduce wind speeds and wind impacts on the prairies. Shelterbelts are also known as living hedges, windbreaks, living fences, or hedgerows. Traditionally they have been used to reduce soil erosion from wind but as technologies have changed (i.e., zero till, chemical fallow) this benefit has been reduced and other costs associated with shelterbelts have increased. Private land owners bear the costs associated with shelterbelts on their lands and only recoup some of the benefits provided through shelterbelts. Understanding the scope of private costs and benefits (economic and non-economic) and barriers to the adoption and retention of shelterbelts by prairie producers will be advantageous in understanding current management practices as well as useful in designing regionally relevant policy related to shelterbelts and their management. This research focuses on the costs, benefits, and barriers to adoption and retention of shelterbelts while reviewing the role shelterbelts play in agriculture and the environment (i.e., greenhouse gas mitigation, habitat provision).

1.2 Statement of the problem

Agricultural practices and technology have changed at a very rapid rate since the early 1900's on the Canadian Prairies. This change in practices and technology has resulted in changes to the use of, and attitudes towards, shelterbelts, as a management practice as well as the costs and benefits realized by private landowners/producers (Casement and Timmermans, 2007). There has been little recent research on the private costs and benefits and impacts of shelterbelts on producers and landowners related to shelterbelts in the zero till and chemical fallow era (Kulshreshtha and Knopf, 2003; Lassoie et al., 2009). Understanding the costs and benefits and the barriers to adoption and retention of shelterbelts that producers are faced with or perceive is essential to understand how management decisions are made in order to design effective and efficient policy.

1.3 Objectives of the Study

The purpose of this research is to explore shelterbelt adoption, retention, and removal on the prairies and to identify the factors that influence producer management and decisions. Identification of factors based on producer opinions from different regions of Saskatchewan. From this investigation, factors that influence shelterbelt management will be identified so that regionally relevant policy recommendations can be formulated based on barriers to future adoption and retention.

The three main objectives of this research are:

1. Identify the economic and non-economic factors that influence producers decisions related to shelterbelt adoption, retention, and removal;
2. Describe the factors (economic and non-economic) that influence shelterbelt adoption, retention, and removal decisions, and
3. Determine potential barriers to adoption and retention of shelterbelts based on the producer surveys.

1.4 Overview of Methods

In the summer of 2013, surveys and informal interviews were conducted in the province of Saskatchewan to collect data on the private costs and benefits of shelterbelts as observed by the landowners/producers. Sixty-one surveys were collected. The comments and surveys were then analyzed to determine different factors related to costs and benefits that are important to producers. In addition, to examining and identifying the economic and non-economic factors related to shelterbelt establishment, maintenance, retention, and removal, the barriers to future adoption and retention were also identified. Finally, policy implications and recommendations were identified based on the factors related to economic, non-economic, and barriers to adoption and retention.

1.5 Thesis Organization

This thesis is organized into eight chapters, the first one being a basic introduction and overview. Chapter two provides background and context within agricultural landscapes with sections on the environment and agronomic implications of shelterbelts. Chapter three provides the background on shelterbelts in the landscape including the past and current social-political context of shelterbelts. Chapter four covers the theoretical framework of adoption and management practices or technologies, such as shelterbelts. Chapter five to seven cover the research that was conducted. Chapter five provides an overview of the survey design and administration. Chapter six goes over the results and analysis of the survey responses. Chapter seven includes the summary of the findings, interpretations, adoption and retention barriers, and recommendations for future policy and research. Chapter eight contains conclusions made from the research.

Chapter 2: Shelterbelts in Agricultural Systems on the Prairies

2.1 Introduction

Shelterbelts play a unique role in agricultural landscapes. They provide many benefits to producers and landowners, society as a whole, and the ecosystem. The majority of the benefits associated with shelterbelts are non-market benefits that require a holistic approach[1] to management in order to be recognized. Like any management decision there are costs associated with shelterbelts use and implementation within the agricultural landscape. Most of the costs associated with shelterbelt implementation, establishment, maintenance, and removal are market based costs. Shelterbelts as a part of an agricultural system are much more complex than they might first appear. There are many ecological, societal, and agronomic impacts associated with shelterbelts and these are intrinsically linked together. This chapter reviews some of the documented costs, benefits, and impacts associated with shelterbelts as well as how these fit into the agricultural landscape and context.

2.2 Shelterbelt Impact on Agricultural Production Systems

Agronomic and production related costs and benefits of shelterbelts have generally been the main focus of shelterbelt planting or removal on the prairies. Shelterbelts can play an important role in agricultural production and historically have been essential to production on the prairies. As agricultural techniques and practices have evolved, the role of shelterbelts in the agricultural landscape has changed. Understanding the impacts that shelterbelts have on current production practices is important for determining what factors influence producer's management decisions related to shelterbelt impacts within their operations. In this chapter some of the benefits, costs, and impacts associated with using shelterbelts in crop production, livestock production, and around the homestead are reviewed.

[1] The holistic approach taken in this research aims to "understand environmental issues in a holistic way, taking into account the interplay of biophysical and social dynamics" as described in Fortuin et al (2013) which suggests the importance of interdisciplinary thought in environmental science education and research.

2.2.1 Shelterbelts in Crop Production Landscapes

Shelterbelts have been widely used and adopted on the prairies since the 1930's for private benefits around homesteads and erosion reduction for crop production (Kulshreshtha et al., 2010). In crop production, prairie shelterbelts traditionally consist of one or two rows around the edge of fields or rows within the field. Using shelterbelts in crop production provides some positive benefits to producers but also imposes costs on the producer. Shelterbelts alter wind patterns and protect the crop from wind related stress. Overall, crops respond favorably to shelter from shelterbelts. It should be noted that the response of specific crops to shelter varies greatly. Drought-hardy cereal varieties and corn have low positive yield responses to shelter, forage crops display moderately positive yield responses, and specialty crops (i.e., fruits and vegetables) and lentils can broadly be classified as highly positive in their response to shelterbelts (Kort, 1988). This section looks to address some of the general benefits and costs of using shelterbelts in agricultural crop production operations.

2.2.1.1. Wind Erosion and Wind Damage Reduction

As technology has evolved, more and more producers have adopted the practice of zero till or minimal till for agriculture production. This has further helped to reduce soil erosion caused by wind as there is continuous cover (stubble or crops) on the field year round. The practice of continuous cropping has reduced the role that shelterbelts play in soil stabilization as now there is continuous ground cover where in the past there was bare soil. These changes in technology have greatly reduced some of the observable benefits related to erosion reduction in the prairies. Often, zero tillage and chemical fallow systems are seen to replace or eliminate the need for erosion mitigation through other measures, resulting in shelterbelts being deemed unnecessary or imposing unnecessary cost or inconvenience (Casement and Timmermans, 2007). Even with the improvements and changes in technology, wind erosion still affects prairies soils each year (Casement and Timmermans, 2007) and shelterbelts play a role in mitigating the amount of soil loss each year through erosion.

In conventional agriculture as well as organic crop production, frequent tilling as well as summer fallowing the land are important weed control techniques. In dry years the soil is more prone to suspension by the wind resulting in erosion and negative impacts on production. This poses a problem when there is no vegetation to stabilize the soil and thus this practice increases the erodiblity of the soils. Properly designed shelterbelts can substantially reduce soil erosion (Brandle et al., 2009b). Reducing soil erosion is highly beneficial for agricultural production as it helps to keep nutrients on site[2], which further results in reduced input use. It is also beneficial to society and the ecosystem as it reduces agricultures impact on other sites (i.e. sedimentation in streams, blowing dust etc.).

Sandblasting of crops by suspended soil particles is also a concern, related to wind erosion, particularly in dry years (Bennell and Verbyla, 2008). Crops that experience sandblast injury may experience lower yields and protein content, delayed maturity, or even mortality (Kort, 1988), which, in turn, impact the profit potential of crops. Shelterbelts trap suspended dust/soil particles responsible for sandblasting and, as a result, help to reduce the physical damage to crops by soil erosion (Cleugh, 1998). The use of shelterbelts to both reduce soil erosion and trap suspended soil particles is an important benefit that positively impacts crop production (Bennell et al., 2007). In addition to sandblasting damaging established crops, small seedlings can physically be buried under deposited sediments resulting in increased seedling mortality (Cleugh, 1998). Since shelterbelts help to reduce erosion and trap suspended particles, they can help reduce these types of losses to crops prior to emergence and during the growing season.

Another positive impact of shelterbelts, hypothesized by Kort is that shelterbelts could also offer protection from winds to crops that are swathed and left in the field to dry (Kort, 1988). Leaving canola in swathes in the fields is a common practice in the prairies where swathed canola left in the field can be susceptible to strong winds. In addition to risking swaths blowing away, light crops such as canola and mustard are more susceptible and shelling out of the seed pods due to strong winds can greatly decrease yields (Kort, 1988). There is a limited number of studies on this particular benefit but it has the potential to be a very important benefit and as a result it warrants consideration for future management and scientific studies.

Overall, shelterbelts play an important role in altering wind patterns around them to both protect the crops from direct wind damage, protect the soil from wind erosion, and reduce yield losses associated with reduced soil quality and crop damage (Kort, 1988; Brandle et al., 2004).

[2] Keeping nutrients on site is beneficial as eroded soils are less productive, require higher inputs, and are prone to additional erosion which imposes additional cost to the landowner/producer (Casement & Timmermans, 2007).

Even with changes to physical cropping technologies, which may negate some of the original benefits and increase certain production costs, shelterbelts remain important for soil and crop protection from the detrimental impacts of wind.

2.2.1.2 Snow Management

Snow is a very important component of the moisture regime in the Canadian Prairies. In agricultural fields on the prairies, snow can account for up to 40% of annual precipitation (Kort et al., 2012). Shelterbelts help with the management of this moisture source through capturing snow and by slowing down wind speeds which helps to distribute and keep the snow in the field (Brandle et al., 2009). Kelson et al. (1999) indicated that shelterbelt trees can be used as “living snow fences” to trap snow and keep it on site as this is an essential part of the moisture regime in semi-arid climates such as that of the Prairies. Once again, shelterbelt design and species selection are important for obtaining the optimum benefits and to keep negative impacts at a minimum.

Some things to consider in regard specifically to snow management include: species selection, orientation, density, distance from the road and in general shelterbelt design (Kort, 1988). These factors need to be considered in order to reduce costs associated with shelterbelts, as improperly designed shelterbelts (i.e., too close to roads) may result in additional snow removal or visibility issues for drivers (Casement and Timmermans, 2007). In addition, increased shelterbelt density will result in increased snow drift size, which may result in delayed spring melt affecting seeding date, particularly in more Northern regions (Brandle et al., 2009) which poses detrimental costs to producers. It is essential in the design and implementation phase to adopt a strategy to maximize net benefit and reduce costs associated with shelterbelts for snow management.

2.2.1.3 Challenges for Production Efficiency

A major challenge in measuring and understanding the benefits of shelterbelts within crop production systems is the complexity and site specific nature associated with shelterbelts (Davis and Norman, 1988). Another major challenge, for incorporating shelterbelts in today’s large industrial scale agriculture, is that the size of the equipment makes maneuvering around shelterbelts a challenge which imposes additional costs on production due to overlap (Taylor, 2010). From a production standpoint overlapping of passes while seeding and spraying results in areas around shelterbelts where the equipment has to maneuver or turn around these obstacles (Kulshreshtha and Rempel, 2014). This directly translates into increased time in field as well as an increase to the amount of inputs (i.e., seed, fertilizer, fuel, etc.) that is required for a field with shelterbelts as compared to one without. As the scale of production on the prairies continues to increase and field production efficiencies are at the forefront, overlapping of seeding and spraying operations will continue to be a major cost associated with shelterbelts from a production efficiency standpoint.

An additional consideration from a production perspective is that shelterbelts take land out of agricultural production, which reduces the total amount of area in crop production per field (Brandle et al., 1992b). This consideration has two sides: 1) less acres seeded could result in less grain to sell, potentially resulting in less profit or 2) less acres to seed resulting in less inputs (i.e., seed, chemical, fertilizer) required and, therefore, less costs. Determining at which point the tradeoff between the two is profitable would be important from an economic perspective in making management decisions related to shelterbelts. In addition, the costs associated with actual removal activities (i.e. fuel, labour, equipment, or hiring contractors) should also be considered. If the costs associated with removal activities are too high than shelterbelts may be retained in order to save on the costs associated with removal activities.

Another challenge created by shelterbelts within production is that shelterbelts result in changes to the microclimate immediately adjacent to shelterbelts. This can cause decreased yields due to competition between crops and shelterbelt species (Kort, 1988); however, yields outside the zone of competition may be increased more than the amount lost immediately adjacent to the shelterbelts. Kuemmel (2003) indicated that yields at field margins, whether adjacent to a shelterbelt or not, display yield depressions. He further suggests that by only comparing crop yields in the sheltered competition zone with the unsheltered yields in mid-field will underestimate the overall benefit of shelterbelts (Kuemmel, 2003). This is an important factor to take into consideration during the design and implementation phase of shelterbelts.

The benefits and losses to yield will largely vary based on site specific characteristics and the crop (Bennell and Verbyla, 2008). Additional maintenance activities, such as root pruning, can help to reduce the competition zone between shelterbelts and crops (Kort, 1988); however, additional maintenance of shelterbelts is labour intensive particularly in the early years (Baer, 1989) which may discourage further adoption of shelterbelts. From a production efficiency standpoint there are many costs and trade-offs associated with shelterbelts in industrialized agricultural production systems.

Shelterbelt design and site specific characteristics will play into the degree of competition (Kort, 1988), profitability (Lovell and Sullivan, 2006), maintenance activities, and the overall success of shelterbelt establishment (Baer, 1989). As a result, of these types of challenges faced by producers, in utilizing shelterbelts in their operations, educational and direct policy measures may be necessary in order for producers to provide shelterbelts at levels within the landscape that are socially optimal (Bowman and Ziberman, 2013). Overall, shelterbelt interactions within an agricultural environment impact both field and landscape levels. This poses a serious dilemma from a land management perspective and makes fully quantifying and understanding shelterbelts costs and benefits within agricultural crop production systems a challenge.

2.2.2 Shelterbelts in Livestock Operations

The most observable use for shelterbelts in livestock operation is for shelter for livestock from the extreme climate of the prairies. Shelter for livestock improves feed use efficiency, water use efficiency, and reduces overall stress on the animals (Kulshrestha and Rempel, 2014). This is beneficial from a production standpoint as it reduces the amount of feed and water required by animals to get them to market weight and as well as reduces mortality rates (Poppy, 2003). Once again, shelterbelt design and management will play a role in the level of benefits or costs realized by the individual land owner in livestock production.

Shelterbelts also provide suitable sites for activities, such as calving, particularly in early spring, where shelter can help to reduce calf mortality and improve feed use efficiency (Kelson et al., 1999). A study done by the PFRA[3] showed that cattle wintered during a severe winter for 102 days from December to March, which included trees for shelter, gained 10.6 pounds more compared to cows that only had shed protection (PFRA, 1980). In addition, Broster et al. (2010)

[3] Prairie Farm Rehabilitation Administration (PFRA)

found that shelter during lambing in shrub shelterbelts reduced neonatal mortality rates by up to 50%. Overall, shelter from shelterbelts is beneficial to the health and wellbeing of livestock.

Another positive benefit that can come from shelterbelts in pastoral agricultural production systems is increased yields of forage and pasture crops (Sharrow et al., 2009). Based on a review of yield impacts of shelterbelts, Kort (1988) concluded that forage crops, such as alfalfa and hay, were highly responsive to shelter with increased yields observed in sheltered fields over non-sheltered. An increased yield in alfalfa and hay fields is highly beneficial to animal producers on the prairies as it will result in more feed available for livestock.

In addition to yield production benefits, shelterbelts placed around water bodies, whether natural or manmade (i.e., dugouts) can capture snow and create drifts on the leeward side to help to replenish these water sources for use in livestock operations (Pomeroy and Gray, 1995). This would be a benefit to animal operations as it would reduce the need to transport water from off-site sources.

Some of the negative impacts and costs of including shelterbelts in livestock operations include increased complexity of management, physical damage to shelterbelts, and fencing/maintenance costs. Shelterbelts used as a part of a livestock operation increase the complexity for the landowner/manager. Animals can cause physical damage to the shelterbelts through rubbing or trampling (Sharrow et al., 2009) as well as consumption of new growth on the trees which can cause further damage to the shelterbelts (Sharrow, 1994). As a result, these factors need to be considered and taken into consideration from a management perspective.

Another cost is fencing. Livestock windbreaks should be fenced off from livestock so as to maintain the shelterbelt health (Brandle et al., 2009) and still allow for shelter (i.e., shade) benefits for the animals. Fencing management, repairs, and costs are something that should be considered when using shelterbelts as a management technique within a pastoral animal operation. Another potential cost of shelterbelt shelter for livestock is that trees can also provide cover for prey animals, such as coyotes or wolves, which may minimize some of their positive impacts. This may result in significant losses if herd members are lost to predation or become stressed due to the presence of predators (Laporte et al., 2010). These types of costs are a concern to the overall profitability of the farm. Another final consideration is woody species and shrub encroachment into pasture lands from shelterbelts or native forested regions (Brandle, et al., 2009). This can reduce the amount of available forage for livestock.

Overall, shelterbelts provide an opportunity to improve the quality of life for the livestock raised within a pastoral setting via providing the animals with shelter from the elements (i.e., snow, wind, rain, heat, etc.) and thereby reducing stress to the animal. The impact of this is considered an overall positive impact with benefits, such as: reduced animal stress, reduced mortality, improved hay and alfalfa yields, and increased/improved onsite water quantity. Some of the costs or negative impacts associated with shelterbelts in livestock operations include: fencing and repair costs, habitat for predators of the livestock, and shrub encroachment. Shelterbelt design and species selection should be done in such a way that maximizes the positive impacts and benefits while reducing the costs and negative impacts.

2.2.3 Shelterbelts around Farmyards

Many of the aforementioned benefits linked to shelterbelts, such as shelter and snow management, are also important beneficial factors related to shelterbelts in yard sites. Shelterbelts around a yard site help to shield inhabitants, buildings, and infrastructure contained within from the extreme elements especially wind (Brandle et al., 2009). Properly designed shelterbelts help to protect people and homes from drifting snow (Pomeroy and Gray, 1995) and blowing dust from roads and fields (Brandle et al., 2009). Factors such as these have the potential to improve the quality of life for people living in rural areas by making the living environment more inhabitable. Furthermore, property values may potentially increase for more “beautiful” yards if the sale of the property is based on people residing on the farmstead (Kulshreshtha et al., 2006). In contrast, if the land is being sold strictly for agricultural purposes the trees on the land could propose additional cost to the purchaser resulting in a potentially lower land value.

Historically, shelterbelt planting was encouraged to promote settlement in rural areas by protecting yard sites from the elements, providing beauty, improving homes energy efficiency, and supplying extractable forest products, such as berries and wood. Additional health benefits may also be realized by the resident of the farmyard [4] such as reduced inhalation of windborne particles (i.e. airborne sediment) (Mao et al., 2013; Abrahams, 2002) and pesticides drift (Ucar, 2001). Prolonged inhalation of airborne particles, dusts, or pesticides can have an array of negative health impacts on the residents of rural areas and shelterbelt interception of these particles is another positive benefit to residents living within tree sheltered farm sites. Most of the costs associated with shelterbelts in farmyards are related to establishment and maintenance of trees around yard sites and snow removal required if shelterbelts trap snow in yards (Brandle et al., 2009).

In addition, benefits such as improved quality of life, beautification, and livability of the land have long been recognized as a major benefit of having trees around settlements and homes on the prairies (Kulshreshtha et al., 2010). These types of benefits may not be directly related to agricultural production; however, they may play a large role in the quality of life of those living in rural landscapes.

2.2.4 Summary of Shelterbelt Impact within Agricultural Landscapes

Many factors including, but not limited to, shelterbelt design, species selection, geography, climate, and operation type will have an impact on the effectiveness of the shelterbelt as well as the benefits, and costs and impacts, which flow from the shelterbelt (Kort, 1988). For the case of crop production there is a delicate balance between the benefits and costs associated with shelterbelts and it is often quite difficult to quantify and observe these impacts directly. Many of the benefits are at a broader landscape level (i.e., reduction of erosion, water protection) while the costs are often related to production impacts and direct private costs (i.e., planting and maintenance, overlap in farm operations). For livestock production the costs of maintaining and protecting the shelterbelt from livestock damage may be detrimental to their implementation (Casement and Timmermans, 2007). In the case of farmyard shelterbelts, there is a general trend that the quality of life and private benefits do outweigh the costs associated with implementation and maintenance.

Shelterbelt design is very important in determining the effectiveness, the economic, and non-economic impacts on operations that will come from shelterbelts of any type. Often the

[4] Some of the private health benefits are similar to those that the public receives from shelterbelts which are discussed in section 2.4.1 Health and Wellbeing.

agricultural benefits and sometimes even the costs associated with shelterbelts are difficult to observe and recognize as they may be at too small of a scale (very site specific even within a field) or too large of a scale (landscape level) for the landowner to recognize or observe. Balancing the observable costs and benefits with the non-observable will be a challenge moving forward. Site specific shelterbelt design is highly important to maximize benefits and bears further research and consideration but is outside the scope of this research. Determining the optimal type of shelterbelt and design of the shelterbelt will be largely dependent on the goals, operation type, operation size, soil and climate limitations, as well as the current suite of incentives and disincentives (i.e., policy) that are in place related to best management practices and shelterbelts (Kort, 1988; Lovell and Sullivan, 2006; Gardner, 2009).

2.3 Selected Environmental/Landscape Level Benefits Associated with Shelterbelts

There are many environmental benefits associated with incorporating shelterbelts into the landscape. A noteworthy positive impact of shelterbelt provision within the landscape is the provision of ecological goods and services to society (Kohli et al., 2008). Ecological goods and services are benefits that result from the normal functioning of an ecosystem (Gordon et al., 2009). In the case of shelterbelts, there are many ecological goods and services provided, some of which benefit society as well as the producer. Brown et al. (2007) and Keoeger and Casey (2007) suggest that it is necessary to differentiate between ecological goods and ecological services to avoid double counting.

This section of the literature review makes a distinction between ecological goods and ecological services. Ecosystem services include provisioning, regulating, and maintenance functions of the ecosystem, whereas ecological goods provide more tangible use benefits. Some of the ecosystem services that result from shelterbelts include: carbon sequestration (Schoeneberger, 2009), maintenance of biodiversity (Lovell and Sullivan, 2006), and protection of soil and water resources (Kulshreshtha and Kort, 2009). In addition, some of the ecological goods that result from shelterbelts in the landscape include the bequest value of shelterbelts (Brown et al., 2007), potential for increased property values (Ma and Swinton, 2011), and recreational opportunities (Kroeger and Casey, 2007).

2.3.1 Ecological Services

Ecological services are considered to be a wide range of natural processes that provide the products and by-products necessary to support human life (Bryan, 2013). The Millennium Ecosystem Assessment (2005) stated that ecosystem services are "indispensable to the wellbeing of all people, everywhere in the world." These types of understandings of the provisioning, regulating, and cultural services of the ecosystem, including agro-ecosystems, is very important to include in the discussion around shelterbelts within agro-ecological systems. Some of the ecological services provided by shelterbelts in agricultural landscapes that are discussed below include: carbon sequestration, maintenance of biodiversity, and protection of soil and water resources.

2.3.1.1 Carbon Sequestration and Climate Change Mitigation

Carbon sequestration is an important ecological service provided by shelterbelts (Schoeneberger, 2009). Integrated agroforestry practices, such as shelterbelts, provide potential opportunities for climate change mitigation if they are incorporated into the agricultural landscape (Johnston et al., 2000). Sequestering carbon through shelterbelts has the potential to help reduce greenhouse gases in the atmosphere and reduce the impact of climate change (Kulshreshtha et al., 2006). Carbon sequestration contributions from shelterbelts have the potential to become more important than some of the traditional values (i.e., erosion control) associated with shelterbelts in the landscape (Brandle et al., 1992b) especially if more robust carbon markets develop (Johnston et al., 2000). The removal of shelterbelts and reintroduction of this land into agriculture is a potential source of carbon to the atmosphere (Kulshreshtha et al., 2010). In addition land use change and conversion to farming has the potential to act as a further source of greenhouse gas emission through the increased inputs (i.e., fuel, fertilizer) that is needed for agriculture on that land (Cook et al., 2009). Loss of shelterbelts is a concern since it may contribute to further climate change.

Several studies have cited shelterbelts as a potential greenhouse gas mitigation strategy moving forward. In the later part of the 20th century some articles indicated the potential of shelterbelts in the prairies for their potential to sequester carbon and mitigate climate change.

Brandle et al. (1992b) suggested that the contribution that shelterbelts made to reducing fossil fuel consumption and capturing carbon could in fact eclipse the traditional values of shelterbelts, such as erosion reduction and yield improvements. Similarly, Kort and Turnock (1999) estimated the total amount of carbon stored in above ground biomass for various tree species on the prairies. They estimated that "a shelterbelt planting program of six million trees and shrubs per year… [in the prairies, could] potentially sequester 0.4 million tonnes of carbon per year" (Kort and Turnock, 1999). This contribution is only taking into account the biomass and does not include the foregone fossil fuel use by removing land from production which would actually increases the benefit that shelterbelts provide in the area of climate change. In addition, these studies focused on above ground biomass and did not estimate below ground carbon capture. If below ground carbon stores are also included the amount of carbon captured in shelterbelts is much higher than estimated.

More recently, new focus has again been placed on the idea of agroforestry trees, such as shelterbelts, being a strategy to mitigate the impacts of climate change and agricultural production. Udawatta and Jose (2012) estimated that the total carbon sequestration under current agroforestry practices in the United States accounted for 530 Tg yr^{-1}. This illustrates the important role that shelterbelts and other agroforestry practices, such as silvopasture, alley cropping, or riparian buffers, could play in carbon mitigation strategies. In addition to the overall landscape level mitigation of greenhouse gases, Bradshaw et al. (2004) indicated the potential important role diversification in crop production schemes for coping with climatic variability. They indicated that complex systems that include perennial vegetation and agroforestry practice enhance the ability of agricultural systems to adapt and cope with climate change and climactic variability (Bradshaw et al., 2004). Shelterbelts and other agroforestry practices can play a role in individual farms ability to adapt and cope with climate change through diversification. In addition, Lal (2010) identified the importance of planted trees in mitigating greenhouse gas emissions and pointed towards global food security as an argument to encourage further planting and management of lands in this manner.

Overall, shelterbelt trees in agricultural landscapes have several important roles to play in the climate change context. Carbon sequestration and storage in biomass is an important benefit associated with shelterbelts. In addition to this benefit, the farmers' ability to cope in the face of climate change and the additional fossil fuel and input use that is foregone by taking land out of production and placing under shelterbelt management are also important factors related to climate change and the greenhouse gas balance of agriculture.

2.3.1.2 Biodiversity Provision

Shelterbelts have the potential to increase biodiversity in agricultural landscapes (Lovell and Sullivan, 2006). Loss of biodiversity within agricultural landscapes is a major concern as agricultural lands interact spatially with lands that provide valuable habitat for a variety of species (Mattison and Norris, 2005). Shelterbelts can help to contribute to biodiversity within the landscape by providing shelter and habitat for flora and fauna (Kohli et al., 2008) as well as acting as corridors for wildlife movement through the landscape (Heitala-Koivu, 2004). Rodewald and Brittingham (2004) have suggested that shelterbelts provide important habitat for migratory birds which are an additional consideration for landscape biodiversity on the prairies.

One of the more notable benefits of the increase in flora and fauna species is that shelterbelts may result in enhanced crop pollination by birds and bees as a direct result of the increased landscape biodiversity (Kuemmel, 2003). Providing and promoting habitat for pollinators is considered a positive benefit, recognized by farmers that could be promoted to further increase adoption (Brodst et al., 2009). In addition to these types of benefits to macro-fauna, shelterbelts also provide an increased level of underground biodiversity, water infiltration, and soil moisture retention as compared to the mono-culture that surrounds them; this is due to the extensive rooting zones and above ground biomass of the perennial plants associated with shelterbelts (Lovell and Sullivan, 2006). These types of ecological services are essential to maintaining a healthy ecosystem. Increased biodiversity makes the landscape more resilient and less susceptible to catastrophic events (i.e., disease and pests) (Kohli et al., 2008).

Some studies have suggested that shelterbelts can have negative impacts on agricultural production through an increase in the incidents of crop pest species, including weeds and their seeds (Kort, 1988) and insects (Danielson et al., 2000). This is a concern as agricultural pests, as well as animals that eat agricultural crops, can cause economic losses to production (Ried, 1997). Shelterbelts also provide the biodiversity necessary for favorable conditions to natural enemies of these agricultural pests (Perovic et al., 2010), understanding and balancing this dynamic is essential for long term sustainability of shelterbelts and agriculture. Several studies suggest that habitat management (Landis et al., 2000) and tree species selection (Perovic et al., 2010; Thomson and Hoffmann, 2010) are very important in the shelterbelt design stage to encourage more natural, beneficial flora and fauna in field margins (Woltz et al., 2012) and to minimize economic losses from invasive and non-desirable competing fauna.

Incorporating shelterbelts into management regimes has the potential to improve the ecological health of agricultural landscapes (Lovell & Sullivan, 2006) and overall improve production regimes which is beneficial to both the private landowner and society as a whole. Increased biodiversity is major benefit of shelterbelts in the agricultural landscape, which also results in several spin-off benefits discussed in other sections related to social and private wellbeing.

2.3.1.3 Soil and Water Protection

The protection of soil resources has been the major driver of shelterbelt adoption on the prairies (Brandle et al., 2009). Shelterbelts reduce wind erosion and Brandle et al. (2009) suggest that "of all the benefits of field [shelterbelts], wind erosion control is the most widely recognized and accepted." Shelterbelts reduce the risk of erosion by reducing wind speed (Brandle et al., 2004). Reducing erosion in the landscape is desirable because as soil erodes, productivity declines largely due to soil organic matter loss (Casement and Timmermans, 2007).

Historically, shelterbelts provided the main source of erosion control within the prairie landscape. However, recent management adaptations, such as reduced/zero tillage and equipment improvements, may result in a lower perceived benefit associated with wind erosion reduction (Kulshreshtha et al., 2010). In addition to production consequences, off-site impacts, such as sedimentation of waterways, are also a serious concern with wind erosion (Kulshreshtha et al., 2006). Along stream ways shelterbelts help to capture and reduce the amount of runoff from agricultural activities including pesticide (Ucar, 2001) and suspended soil interception (Brandle et al., 2009).

Shelterbelts can also act as a means to protect water sources in several ways. Wide shelterbelts can serve as buffers around riparian areas to help reduce the amount of inorganic compounds (i.e., pesticides) that reach waterways (Szajdak and Zycynska-Bolabiak, 2013). Another way that shelterbelts can aid in water quality protection is by slowing down runoff velocity to help reduce downstream flooding (Henry et al., 1999). In addition, shelterbelts impact water quantity through snow capture by shelterbelt trees or rows. The captured snow in shelterbelts contributes to groundwater and surface water recharge (Kort et al., 2012)

Protection of waterway quality and quantity is a benefit to all facets of sustainability. It ensures long term sustainability and viability of water resources for use in ecosystems, the economy, and by the society. The protection of waterways is and could be an important benefit that is captured from the use of shelterbelts in agricultural landscapes.

2.3.2 Ecological Goods

There are many benefits from shelterbelts that could be considered or contribute to the ecological function within agricultural landscapes. Shelterbelts play a critical role in the conservation and preservation of ecological systems within agricultural landscapes (Bonifacio et al., 2011). Ecosystem goods are the tangible materials that are produced as a result of the ecosystem function within the landscape (Brown et al., 2007). In the case of shelterbelts there are several tangible goods that can be classified as ecological goods, some of them include: bequest value, improved property values, and recreational related opportunities (Kroeger and Casey, 2007).

2.3.2.1 Bequest Value

Bequest value is the option or desire to maintain resources so as to have the option to leave them for current and future generations (Field, 2001). This can be considered an ecological good as landowners and producers may be motivated to maintain a certain level of ecological goods and services in order to leave a healthy functioning environment/ecosystem to someone else (i.e. their children) (Field, 2001). With the case of agricultural landscapes and homesteads, there is often a strong incentive or effort to keep farms within a family for multiple generations. This type of goal or desire would influence management and increase the degree to which long term thinking is employed. It is advantageous for the process of farm transfer from one generation to the next to be gradual and over time (Fetsch, 1999). This type of transfer from one generation to the next does complicate management but also adds an additional element of influence in decision making. With bequest value, producers today are deriving utility from the ability to bequest the benefits to the next or future generation (Fernandez, 2006).

An experimental choice study conducted by Jianjun et al. (2013) found that households with younger family members at home placed a higher value on and a greater willingness to accept programs aimed at improvements (i.e., fertility) on cultivated lands. They equated this choice with bequest value options. In addition, Bryan (2013) suggested that risk and uncertainty over the future may influence landuse change decisions. Minimizing risk for both current opperations and future uses, including bequest values, will influence producers management decisions related to tree planting and shelterbelts within the landscape (Bryan, 2013). This desire to bequest land and its inherent productivity in the future has the potential to be very influential in the adoption of best management practices.

2.3.2.2 Property and Option Value

Similar to bequest value, option value is maintaining or preserving something with the option that it could be utilized or needed at some point in the future (Field, 2001). Many functions of shelterbelts display characteristics of option value. For example, people may be willing to preserve their shelterbelts as they deem that they may be of value to them in the future. In other words, in areas such as the prairies that are prone to drought (Baer, 1989), shelterbelts may be kept as they play a crucial role in the moisture regimes in dry years (Kort et al., 2012) as well as reducing soil losses through erosion. For these reasons, producers may opt to keep shelterbelts during wet years so that they have them available for future years when the benefits are more observable. These are some of the examples of benefits and risk management associated with shelterbelts (i.e., wildlife habitat, beauty) that display option value characteristics. The preservation of shelterbelts for the option to enjoy/use the shelterbelts and the services that they provide at some future time is another element to consider when valuing shelterbelts and looking at decision making processes and policies.

The direct value of shelterbelts on property value will depend on many factors but is another impact to be considered in shelterbelt management and design. Kulshrestha et al. (2010) suggested that shelterbelts around farmyards could add value to rural properties; however, this additional value may be difficult to measure. Often in rural settings, properties may not be sold at market value (i.e., sold to family members at discount) or the purchaser may not be intending to reside in the yard site. In the former case, the sale price may not be reflective of the true value of the yard, the beauty, or the sentimental value. In the latter case, if the property is only being purchased for its agricultural land value/base and not the homestead, the shelterbelts may be of no value or actually impose additional costs to the new landowner (i.e. removal costs). Some examples of the extra costs that shelterbelts could impose include the cost of tree removal to convert to agricultural land, additional maintenance costs associated with abandoned yards, wells, etc., or overlap of seeding and spraying operations around the yard site. If instead properties are being sold as acreages or just for the yard sites, the established trees around the yard site will provide some increase in the property value over a similar property with no trees.

These things considered, a well maintained, treed yard site should still be of higher property value than a poorly maintained or un-treed property, for residential purposes (Kulshreshtha and Knopf, 2003). However, in the case of a field shelterbelt or an abandoned yard site, there may be no additional benefit to property values as a direct result of shelterbelt trees and in most cases, there may be additional costs associated with maintenance of removal. When considering the benefits associated with shelterbelts, option value and property value benefits are going to be context-dependent but impact on land and resale value should be considered.

2.3.2.3 Recreational Opportunities

Shelterbelts also provide opportunities for land owners to access or make use of recreational and use-related opportunities. Shelterbelts provide both extractive and non-extractive resources that can be utilized by landowners for recreational purposes. Landowners can enjoy their shelterbelts in similar ways to those that society can, such as enjoying shelterbelts for their beauty and green space; however, landowners also experience additional non-extractive recreational opportunities, such as bird watching, hiking, or wildlife viewing within their own private shelterbelts.

In addition to these non-extractive recreational activities, the opportunity for landowners to enjoy extractive recreational activities also exists. For example, land owners can enjoy the habitat for wildlife on their land and participate in extractive recreational activities, such as hunting, which is enhanced by the habitat that are contained in and linked by shelterbelts. Some other extractive recreational activities could include berry picking, mushroom harvesting, or wild flower picking.

Both the extractive and non-extractive recreational activities available to the land owner will vary depending on the specific site and shelterbelt design. In addition, the degree to which the landowner or producer utilizes these potential benefits will impact the amount of influence, if any, these types of opportunities hold over specific shelterbelt management decisions.

2.3.3 Summary of Environmental/Landscape Benefits

In summary, the environmental benefits/ecological services that are provided by shelterbelts benefit the producer, society, the environment, as well as future generations. Carbon sequestration, biodiversity contributions, improved aestheticism of the landscape, and erosion controls are just a few of the services provided by shelterbelts that contribute to enhanced environmental quality. Many other ecological goods and services flow from shelterbelts and these services are generally undervalued in the market (i.e., by private land owner and society). From an environmental protection and enhancement standpoint, the provision of shelterbelts in the landscape enhances the resilience of the landscape to potential shocks (Kohli et al., 2008) and is therefore desirable to society.

2.4 Social Impacts of Shelterbelts

In addition to the private costs and benefits of shelterbelt provision, there are public or social benefits. Social benefits provided by shelterbelts include the ecological goods and services (Mize et al., 2008). The majority of social benefits cannot be valued via the traditional market (Kulshreshtha et al., 2006) which can make them difficult to build into economic models with any degree of economic or dollar related benefits. Non-market valuation techniques, such as hedonic pricing or contingent valuation (CV), are potential tools that could be used to calculate a monetary value for services from natural resources (Field, 2001) although these are just indicators and may not be able to capture the value in its entirety.

Some attempts have been made to quantify these benefits using non-market valuation methods. For example, Grala et al. (2012) conducted surveys and used the contingent valuation method to determine the willingness to pay for aesthetics associated with shelterbelts in Iowa. This study determined that people were willing to pay (hypothetically) on average between $4.77US and $8.50US for a fund that would plant more trees and convert land into shelterbelts. Studies like the one by Grala et al. (2012) illustrate that there is a value to the improved aesthetics provided by shelterbelts and these types of studies provide further economic validation for government programs/policy aimed at increasing the provision of shelterbelts in the landscape.

There is a potential for value related to ecosystem services, such as carbon sequestration, wildlife habitat, recreational opportunities, and aesthetic quality improvement to be captured in a market model using these non-market evaluation techniques (Grala et al., 2012). It is worth noting that services related to ecosystem-function can lead to social and economic benefits that can lead to additional spin-off benefits to society (Kulshreshtha et al., 2006). The remainder of this section will focus on some of the social benefits of improved health and wellbeing and landscape aestheticism associated with shelterbelts within the landscape.

2.4.1 Health and Wellbeing

Trees within the landscape benefit not only the landowner but also other members of society who can enjoy the benefits of trees in the landscape. Similar to the quality of life benefits enjoyed by individual landowners resulting from diversity in the landscape and trees around their homes, society as a whole may also benefit from the provision of green spaces and in particular trees in the landscape. Nielsen and Hansen (2007) conducted a mail out survey that collected information on proximity "green spaces" and health factors. They concluded that the presence of green spaces has a positive impact on mental and physical wellbeing. They further suggest that the promotion and maintenance of green space may in fact reduce medical/healthcare costs in western developed nations (Nielsen and Hansen, 2007). Similarly, van den Berg et al., (2010) indicated that participants in their study who lived within 3 km of green spaces were less impacted by stressful life events. In addition, the Millennium Ecosystem Assessment (2005) indicates the importance of human survival on the function of ecosystems, which support productive agricultural activities. Based on these types of studies, shelterbelts in the landscape may provide health and wellbeing benefits to both private owners, as previously mentioned, and society as a whole.

2.4.2 Landscape Aestheticism

Shelterbelts enhance the aesthetic appeal of the landscape. Shelterbelts surrounding farmyards are particularly valued for increased aesthetics and privacy enhancement; both of these contribute to the overall wellbeing of homeowners/residents (Brandle et al., 2009). Lovell and Sullivan (2006) suggest that buffer strips, such as shelterbelts, have social value as well because they "impact the visual quality of the country side by introducing variability into what is often a homogenous landscape where monoculture crops dominate." Surveys conducted by Grala et al. (2010) indicate that the visual appeal of field shelterbelts is more important to non-farmers than to farmers. Furthermore, the visual appeal of the landscape is of value to society and diversifying the landscape contributes to enhanced ecosystem services (Grala et al., 2010). Improved aesthetics, visual interest, and diversity related to shelterbelts in the landscape are an ecological service provided to both producers and society as a whole.

2.4.3 Summary of Social Impacts

Shelterbelts provide benefits to society, in addition to the private benefits received by landowners, through ecological goods and services that flow from them. Shelterbelts may also play a role in the overall health and wellbeing of society. In addition, shelterbelts are important from an aesthetic and visual diversity perspective within agricultural landscapes. Shelterbelts provide diversity and beauty in the landscape, although this value is difficult to quantify without non-market evaluation techniques. These types of societal benefits are touched on in this section to provide an overview of the breadth of possible benefits that flow from shelterbelts within the landscape. It should be noted that providing these benefits through shelterbelts may impose a cost to society if government policy and public funds are directed to encourage additional shelterbelts. Further study would be required to determine the level of shelterbelts that is optimal when costs are weighed against benefits.

2.5 Private Economic Context

In addition to many of the non-economic impacts of benefits, shelterbelts impose some economic costs and provide some economic benefits. This section will review the economic context in which agricultural land owners and producers make decisions related to shelterbelts.

Agricultural producers face many trade-offs and make many management decisions related to their operation each year. Understanding the basic economic context in which decisions related specifically to shelterbelts are made, as well as the challenges and barriers producers face related to shelterbelts, is essential for policy design and implementation. The remainder of the section will briefly cover the cost of implementation, maintenance, and removal activities within the theoretical economic context.

2.5.1 Private Costs and Benefits Associated with Shelterbelts

Shelterbelts provide an array of private costs and benefits (Kulshreshtha and Knopf, 2003). The private costs and benefits, associated with shelterbelts, are by definition the costs and benefits that are captured entirely by the producer or land owner (Kulshreshtha et al., 2010). The producer makes specific land management decisions regarding shelterbelts based on their private costs and benefits. The rational producer weighs the cost of implementation and maintenance against the private benefits he/she will receive from the shelterbelts; if the costs of implementation and management are too high the producer will opt to not include shelterbelts in their land management plans.

The major private costs associated with shelterbelts are related to the opportunity cost of other land uses, establishment, maintenance, and crop competition (Brandle et al., 2009). The private benefits to farmers provided by shelterbelts can include: potential for improved yields (Brandle et al., 2004), more uniform snow capture (Scholten, 1988), improved aesthetics particularly with farmyard shelterbelts (Kulshreshtha and Knopf, 2003), energy conservation (Kulshreshtha et al., 2006), and reduced erosion/soil stabilization (Mize et al., 2008).

Some of the benefits of shelterbelts such as reduced soil erosion, crop protection, and snow capture can enhance the productivity of the land and potentially contribute to increased land values for the producer (Grala et al., 2012); however, if the private cost of implementing and maintaining shelterbelts is greater than the private benefits, shelterbelts will not be provided at socially optimal levels. In most cases some shelterbelts will be provided at some level but the public benefits (i.e., carbon sequestration) may greatly outweigh the private ones (i.e., increased yields) (Pretty et al., 2001); therefore society would be better off if a greater amount of shelterbelts were provided in the landscape than would be supplied in a competitive market model.

2.5.2 Shelterbelts and Market Failure

The ecological services from shelterbelts providing social benefits are examples of positive externalities. These externalities have societal benefits and have the characteristics of public goods (Shrestha and Alavalpati, 2004). The nature of public goods indicates that they are non-rival and non-exclusive and there is a strong incentive to free ride (Field, 2001). The inherent nature of public goods suggests that the incentives are low to producers to provide these ecological goods/social benefits at a socially optimal level (Shrestha & Alavalpati, 2004). These ecological and social benefits have the characteristics of public goods in that producers, who bear all the cost of providing shelterbelts, do not have a strong incentive to provide shelterbelts at the level that is socially optimal (Q*, P*) where total social marginal cost is equal to total social marginal benefits (total MC = total MB).

In the case of shelterbelts, total marginal benefits flowing from shelterbelts to society are greater than the marginal private benefits of providing shelterbelts by the individual (Nolet et al., 2009). The private landowner/producer bears all of the costs of shelterbelt establishment, maintenance, and removal but does not capture all of the benefits associated with shelterbelts (due to the presence of externalities). This would result in ecological goods and services associated with shelterbelts to be undersupplied in a competitive market (Nolet et al., 2009). This in turn could result in negative externalities associated with the loss of/under-provision of the ecological goods and services associated with shelterbelts. Some of the negative externalities could include loss of soil through erosion (Casement and Timmermans, 2007), reduced biodiversity (Mize et al., 2008), reduced quality of life and health indicators (Grala et al., 2010), and water pollution from pesticides or erosion (Casement and Timmermans, 2007).

2.5.3 Summary of Private Economic Context

In today's industrial zero till era of farming, some of the original motivations for planting shelterbelts on land may be shifting to more broad landscape level benefits. There is significantly less concern placed on losses of soil through wind erosion as continuous cropping and zero tillage have largely replaced summer fallow and conventional tillage practices. As farming has changed, so have the attitudes about shelterbelts. With larger equipment, more land per farm, and new farming technologies, it is not farfetched to consider that shelterbelts may no longer be a major fixture of the prairie landscape. In spite of all of these changes, shelterbelts still hold other values to society as a whole through the provision of ecological goods and services which have the characteristics of public goods (Kulshreshtha and Knopf, 2003). This means that it is not possible to exclude those who do not provide the shelterbelts from enjoying the ecological or social benefits of them,

2.6 Summary

There is a wide suite of benefits and costs associated with shelterbelts in agricultural systems. Many of the benefits are external to the agricultural producers and are social or environmental benefits. The literature review provided insight into the potential suite of benefits and costs that are related to shelterbelts. These benefits and costs, both economic and non-economic, provide detail into some of the trade-offs and volume of considerations that producers face when making management decisions related to shelterbelts. The literature review helped to shape the study survey as well as provided a baseline for comparison between the factors identified by producers. This chapter's purpose was to serve as an overview and is not considered to be an exhaustive list of all possible economic or non-economic factors related to shelterbelts. The addition of producer perspectives, through the survey analysis, will serve to improve upon the list of potential benefits and costs (both economic and non-economic) influencing producer management decisions related to management and adoption of shelterbelts.

It is also worth recognizing that the individual land owner/producer may not recognize all of the benefits and costs associated with shelterbelts on their land. The costs associated with providing, establishing, maintaining and/or removing shelterbelts are in the majority borne by the land owner/producer whose agricultural operation includes shelterbelts. This type of situation will, if left to the free market, result in a level of shelterbelt provision in the landscape that is lower than socially desirable, this therefore gives a strong argument for government intervention and policy to encourage/increase/maintain the use of shelterbelts within agricultural landscapes in order for the amount of shelterbelts provided to reach socially optimal levels.

Chapter 3: Shelterbelt Policy on the Canadian Prairies

3.1 Introduction

Shelterbelts have been recognized as an important tool in Canadian prairie agriculture since the late 1800's. As early as the 1870's the government of Canada recognized the importance of trees on the prairies and tree planting was extensively promoted to encourage settlement in the west (Watters, 2002). The severe drought of the 1930's, joined with farming practices of the day combined to create conditions on the prairies known as the "Dust Bowl"; soil erosion by wind was a serious problem at this time and shelterbelt trees were identified as a way to reduce the impact the harsh prairie conditions had on agriculture production and settlements (Brandle et al., 2009). The federally-run tree nursery at Indian Head, Saskatchewan was instrumental in developing and providing prairie hardy varieties of tree seedlings to farmers at no cost. The center also provided technical information and support for producers (Kulshreshtha et al., 2010). From 1903 to 2009 over 600 million trees and shrubs were distributed through the Prairie Shelterbelt Program and its tree nursery (Wiseman, 2009). This success, measured by tree distributions, highlights that policy measures and practices will play a significant role in the decisions that producers make (Pretty et al., 2001) related to the implementation of shelterbelts. It is for this reason that past and present policy measures in the Prairies are considered and reviewed. Policy (or lack of policy) has and will continue to play an important role in the choices that producers make related to shelterbelts. The goal of this chapter is to understand the context in which shelterbelts have been implemented to date as well as the current changes in policy measures that will be impacting producer's management decisions going forward.

3.2 Case for Policy Intervention

There are external benefits associated with shelterbelts in the landscape, with the characteristics of public goods; therefore, the quantity of shelterbelts, and in turn the benefits supplied by the free market will be significantly less than socially optimal quantity. As a result of these characteristics government policy/provision is often required to encourage the incorporation of shelterbelts in the landscape (Kulshreshtha et al., 2006). Agricultural policy is a key factor that strongly affects land-use decisions (Mattison and Norris, 2005) and policy aimed at increasing the provision of ecological goods and services as well as environmental and social benefits, such as those associated with shelterbelts, can take many forms and including a diverse suit of policy measures is most desirable (Pretty et al., 2001). A major challenge to policy, directed at agri-environmental landscapes, is to balance food production with sustainability (Pretty et al., 2001). There are many potential ways that governments could go about increasing the provision of shelterbelts in the landscape. Some of the suites of policies that can be used for this type of sustainable management practice include: information based policy (Pretty et al., 2001), direct policy (Field, 2001), and economic instruments (Field, 2001). The remainder of this chapter will focus on the strategies and policies that have been used on the Canadian Prairies, both historically and currently, related to the adoption and use of shelterbelts.

3.3 Evolution of Shelterbelts on the Prairies- Practice and Policy

Shelterbelts have a long history on the Canadian Prairies. Since the early days of settlement on the Prairies people have recognized and utilized the many benefits that trees and shelterbelts can have on the way that they live (Wight, 1988). In Saskatchewan, publicly subsidized incentive programs and extension services have been the types of policy related to shelterbelt development and promotion (Kulshreshtha et al., 2006). In 2012, the federal government announced the discontinuation of the shelterbelt programming policy including tree provision and extension services (Wilson, 2012) and it is after these policy changes that this research is being conducted. The remainder of this chapter focuses on the history of shelterbelt policy and promotion on the prairies as well as the current changes which have seen the federally funded provision of trees to land owners discontinued.

3.3.1 Period of Afforestation to Encourage Settlement of the Prairies 1870-1920's

In Canada, there is a long history of federally funded tree planting and shelterbelt focused programs. These programs have worked to address the external benefits to society and the high costs to landowners related to shelterbelt provision (Kulshreshtha and Knopf, 2003). As early as 1870, the government developed a tree planting program to encourage settlement by enhancing the prairie landscape with trees (Kulshreshtha et al., 2010). In 1886, the federal government established a research farm at Indian Head, Saskatchewan, with a mandate to find plant varieties adapted to the harsh prairie conditions and to provide technical support to new settlers (Agriculture and Agri-Food Canada, 2011a). In these early years, the focus of the programming was on hardy variety development, technical support, and the provision of trees for shelter, fuel, and timber (Bubar, 1984).

It was recognized by the federal government that trees provided a variety of benefits to the settlers (Kulshreshtha et al., 2010). The cost to settlers to develop varieties and purchase trees was very high; therefore, in 1902, the government developed a subsidized program to provide trees to farmers free of charge (Howe, 1986). This was done with the objective of increasing the number of trees in the landscape. This program continued until the 2012 announcement of closing the Indian Head nursery, with 2013 being the last year of such distribution of trees (Wilson, 2012). From 1887 to 1914, the emphasis of the government funded tree distribution program was for the protection of homes, gardens, crops, and livestock, as well as for a source of timber and fuel (Kulshreshtha et al., 2010). This program was very successful and by 1914 trees planted as a result of the program outnumbered settlers in the prairies by 30 to 1 (Kulshreshtha et al., 2010).

3.3.2 Legacy of Land Degradation and Droughts Resulting in Promotion of Shelterbelts 1930's-1990

With the onset of the devastating drought of the 1930's and the ensuing "Dust Bowl" it was clear that the land management practices of the time needed to adapt to the harsh climate (Courtright, 2011). As a result of the combination of low precipitation levels, crop failure, and highly erodible soils, large volumes of prairie soils were blown away in the great dust storms of the "dirty thirties" (Schubert et al., 2004). This "Dust Bowl" was one of the worst environmental disasters in North American history and it was devastating to agriculture and the economy on the prairies (Cook et al., 2009; Littlefield, 2012). During this era, the government-funded center at Indian Head became the keystone research center for fighting the "dust bowl" on the prairies (Agriculture Agri-food Canada, 2011a). In 1935, the Prairie Farm Rehabilitation Administration (PFRA) was established and funded by the federal government with a mandate to rehabilitate the devastated prairies (Bubar, 1984). Shelterbelts were encouraged at this time through subsidized tree provision, education, extension, and technical assistance (Kulshreshtha and Knopf, 2003).

The shelterbelts were promoted on the basis that they helped to reduce erosion and capture much needed moisture in the form of snow; many miles of field shelterbelts were planted as a direct result of the tree seedlings and technical assistance provided by the PFRA mandate (Kulshreshtha et al., 2010).

Shelterbelts have continued to be a management technique used by farmers to lessen the severity of drought effects (i.e., erosion, snow capture for moisture) and protect soil resources (Kulshreshtha et al., 2010). From the 1930's to the mid 1990's, conventional tillage with summer fallow rotations was the norm on the prairies. Severe droughts in the late 1980's resulted in some of the largest plantings in the history of the free tree era. From the late 1980's to the early 1990's many of these trees were planted through the Save Our Soils initiative (Kulshreshtha et al., 2010).

3.3.3 Era of Conservation Tillage from Mid-1990's to Early 2010's

The provision of trees for shelterbelts at no cost to farmers (economic instrument-incentive), research, education, and technical assistance (information based policy) from the Indian Head Tree Nursery and the PFRA continued into the twenty first century (Agriculture and Agri-Food Canada, 2011a). Additions and changes have occurred to the federal programing since the 1930's (Kulshreshtha et al., 2010); however, the structure and function of the program largely remained the same with a focus on research, development, technical assistance, and included the subsidized provision of trees for shelterbelts. More recently higher than average precipitation levels, advances in seeding technology, increases in equipment size, increases in average farmer age, and increase in proportion of rented lands have all been contributing factors to a recent trend in decreased planting of shelterbelts on the prairies (Kulshrestha and Rempel, 2014). These factors contribute to increased private costs and lower demand for shelterbelt as an agronomic management practice on the prairies.

In 2006, Kulshreshtha et al. (2006) did a study attempting to quantify the benefits associated with the trees distributed through the Shelterbelt Program between 1981 and 2001. They estimated a range of CAD$105-600 million for the value of the benefits associated with the Shelterbelt Program. This estimation used a benefit transfer method and not all of the benefits of shelterbelts were captured due to limited data; therefore the value of the benefits flowing from the Shelterbelt Program is considerably higher than this estimate. In comparison the total discounted cost, using a 10% discount rate, from the program in the same time period was CAD$13-19 million (Kulshreshtha et al., 2006). In 2011, the Indian Head Research Farm celebrated 125 successful years of research, technical support, and programming (Agriculture and Agri-Food Canada, 2011a). In 2012 the operating cost of the center was CAD $3.5 million and it distributed nearly 3 million trees (Friesen, 2013).

3.3.4 Policy Changes and an Uncertain Future for Shelterbelts on the Prairies

In the spring budget of 2012, the federal government, under Conservative Prime Minister Stephen Harper, announced that the shelterbelt program and Indian Head Research Branch would be transferred to the provinces or potentially to the private sector (Wilson, 2012). The Shelterbelt Center at Indian Head was set to close by the end of 2013 (CBC News, 2012). This announcement has major implications for producers as well as for the future of shelterbelts on the prairies. This change in policy has the potential to impact land use decisions regarding shelterbelt implementation within the prairie landscape. The loss of subsidized trees and publicly funded research could mean a dramatic change in shelterbelt provision in the landscape. In addition, due to closure and discontinuation of the program, the signal to producers and landowners is that shelterbelts are no longer necessary for sustainable agriculture on the prairies[5]. Davey and Furtan (2008) in their analysis of factors that influenced producers decisions to adopt or not adopt conservation tillage, concluded that producers learn about the effects of a new technology through observation and they strongly caution against the reduction of support for extension and demonstration activities. This is potentially a major concern moving forward for shelterbelts in light of the impending shelterbelt center closure at Indian Head.

3.4 Summary

Shelterbelts have a long and storied history on the Canadian prairies. They are generally considered a fixture on the landscape. From the late 1800’s to 2012 shelterbelt and tree provision

[5] In 2014, the summer after the data was collected for this research, the center at Indian Head has been leased to HELP International. This organization is planning to continue the distribution of trees to landowners, including acreage owners, at a minimal cost to purchase each tree seedling (HELP International, 2014). The research for this thesis was conducted in the interim between the announced closure and the lease to HELP and this influences the responses and the analysis.

was federally funded on the prairies to both encourage settlement and improve the sustainability and viability of agriculture in the drought-prone areas. Recent changes to agricultural farm structure and technologies have changed the way that shelterbelts are viewed politically[6]. It was in this time of an uncertain future for shelterbelts and the Shelterbelt Center at Indian Head (Friesen, 2013) and after these policy changes that this research has been conducted. The Shelterbelt Center is now being leased to HELP International, trees can be purchased from the center for a minimal cost (HELP International, 2014). This new development is the beginning of a new era for tree distribution, planting, retention, and maintenance on the prairies.

[6] After the decision to close the center was made the federal government indicated that the shelterbelt program has done its job and is no longer needed due to changes in agriculture from how things were done a century ago. Agricultural Minister Gerry Ritz said “Farmers don’t farm like they did when (the shelterbelt program at) Indian Head came into being …we’re wanting to make sure that government is focused on the right programs for tomorrow’s agriculture” He went on to say that minimum tillage, continuous cropping practices and chemicals now provide erosion control and tree shelterbelts are no longer as important as they used to be (Friesen, 2013)

Chapter 4: Adoption Theory Theoretical Framework

4.1 Introduction

Producers on the prairies have many decisions to make surrounding management of farm business. Changing management techniques is often a gradual process that takes place over an extended period of time. Within the agricultural context, many factors influence the decision making processes of producers. Some of the factors are external to the producer (such as policy or market instruments) but others are directly related to the producer's world view. This chapter provides a brief overview of some of the theories used to examine adoption of agricultural innovations and management techniques. Income, utility, and innovation diffusion paradigms are touched on as well as a basic overview of other factors with potential to influence producer's management decisions related to shelterbelts. In addition, potential influences and barriers to adoption of new ideas, such as having shelterbelts or removing shelterbelts, are addressed in the later part of this chapter.

4.2 Adoption Theory

Three adoption paradigms are prevalent in agricultural conservation and technology adoption literature. These theories are: income paradigm, utility paradigm, and innovation-diffusion paradigm (Upadhyay et al., 2003). The income and utility paradigms are grounded in theory of the neoclassical household production model (Fernandez, 2006). The innovation-diffusion paradigm is more common and favored by rural sociologists (Upadhyay et al., 2003). Based on a review of the literature, Davey and Furtan (2008) suggest that adoption decisions by farmers are made based on four characteristics of the technology innovation: relative profitability, relative risk, initial costs, and relative complexity of the technology/innovation (Davey and Furtan, 2008). Relative profitability and initial costs fall under the income and utility paradigm with the level of risk and complexity falling into these as well as the innovation diffusion-adoption paradigm. It is for this reason that a blend of the three paradigms is considered for this research.

4.2.1 Income and Utility Paradigms

Income and utility theories suggest that agricultural producers make decisions based on profit maximization and utility maximization principals. These theories are embedded in economic theory and equate producer's decisions with their ability to maximize profit or utility. Within the income paradigm, producers will only adopt new practices or types of technologies if the new practice will increase the farms net returns (Cary and Wilkinson, 1997; Yang and Zhu, 2013). The utility paradigm expands upon the income paradigm to include additional factors that the producers respond to, including: environmental quality, social benefit, and/or altruism (Upadhyay et al., 2003).

Researchers such as Baron (2001) and Jones (2010) have indicated that by utilizing the utility maximization paradigm in conjunction with the income paradigm brings additional clarity regarding firm's decisions. Both of these paradigms provide theory that is transferable to the agricultural producer's decisions related specifically to shelterbelts adoption or removal. Brandle et al. (1992b) examined shelterbelts using this approach and concluded that shelterbelts as a long-term investment provide opportunities to enhance productivity and as a result profitability. In addition, they cited that although additional utility related benefits were difficult to quantify, they do provide additional positive value to shelterbelts (Brandle et al., 1992b). Both income and utility paradigms suggest that for adoption to take place the practice must be economically profitable and/or provide additional utility (enjoyment/benefit) to the producer. This is in line with what Davey and Furtan (2008) concluded about producer's management decisions related to conservation tillage in the Prairies, which indicated that producers make decisions based on economic factors associated with new innovations and technologies.

4.2.2 Innovation-Diffusion Paradigm

The final paradigm considered for the context of shelterbelt adoption or removal on the prairies is the innovation-diffusion paradigm. This theory highlights the role of information, risk, and social status within the community or social network as factors in the decision making process (Upadhyay et al., 2003). This theory follows the pattern that new information and technology adoption or removal are incorporated into practice by a few innovators and early adopters and that this behavior is then diffused to the majority (Rogers, 2003). There are considered to be five stages in this paradigm along the path to adoption: 1) knowledge, 2) persuasion, 3) decision (accept or reject), 4) implementation, and 5) confirmation (Rogers, 2003). This theory can provide some insight into understanding why and how certain decisions related to shelterbelts are made to either adopt, retain, or remove.

The innovation diffusion theory argues that communication, information, and influence alter the behavior of individuals within social networks (Wejnert, 2002). This paradigm suggests that adoption will occur by the majority as they see the success of the early adopters and innovators. This is in line with what Davey and Furtan (2008) found in the context of conservation tillage. They suggested that technology and innovation adoption takes place over a period of time with large firms more likely to adopt than new or small firms and some producers opting to wait and let "the users of the technology learn about the shortcomings in the design and modify the product" before they (the late adopters) adopt (Davey & Furtan, 2008). This indicates that user-friendliness and risk averse nature will impact the rate of adoption of a technology. Information diffusion from those with experience with the technology to those without will influence the rate and degree to which a new technology or innovation is accepted and adopted in the landscape.

This research aims to take into considerations the basic guiding principles of income, utility, and innovation-diffusion paradigms for examining adoption, retention, and removal of shelterbelts in the Canadian prairies. This entailed asking producer's opinions, goals, values, and decisions making processes related to shelterbelts, and through that examining their thoughts and opinions of shelterbelts. The influences of income, utility, and innovation-diffusion theory were considered. This approach was taken due to the complex nature of adoption decision making process within the context of agricultural producers' land management decisions. The blend of income, utility, and innovation diffusion paradigms allows for consideration of economic, personal, and social influences in the decision making and adoption process.

4.3 Additional Influences on Agricultural Producers and Barriers to Adoption

In addition to the paradigms related to producer's adoption of new innovations, technologies, and practices, other factors of influence can play a role in the decision making process and influence the producer's personal worldview and the paradigm that it corresponds with. Personal values, perceptions, goals, social context, financial situation, and land tenure are all factors that contribute to the willingness or ability to undertake new innovations or management practices. In addition, as mentioned in Chapter 3, shelterbelts can also have an influence on producer decisions by impacting the social, economic, or ecological context that they are operating within. The remainder of this chapter looks at how the values, perceptions, and goals as well the social, financial, and land tenure situations of producers can influence their decision making process related to the adoption or removal of shelterbelts.

4.3.1 Producers Values, Goals, and Perceptions

Producer's values, goals, and perceptions of an innovation or technology will play a major role in their willingness to adopt. Perceptions surrounding the level of risk associated with the new technology along with how risk adverse the producer is will influence decisions related to the technology or innovations that are adopted or not adopted. Producers who are risk takers and early innovators will be the most likely to adopt first while those who are risk adverse will wait to see if the early adopters have success (Rogers, 2003).

In addition, individual goals and values associated with their farming operation are major drivers in the decision making process related to land management (Pannell et al., 2006). For example, Lapple and Van Rensburg (2011) identified a difference between early and late adopters of organic agriculture. They concluded that early adopters were less risk adverse and more aware of environmental impacts than late adopters (Lapple and Van Rensburg, 2011). This illustrates the important role that individuals' goals, values, and perceptions (particularly related to risk) play in the decision making process related to agricultural management techniques, technology, and innovations. It is also necessary to consider that farmer's values, goals, and perceptions are not a static entity and that they use additional/available information to update their beliefs (Maertens and Barrett, 2012). How producers view the risk associated with new techniques, innovations, and technologies will influence individual management practices.

4.3.2 Producer Social Learning and Social Networking

Societal influence and participation within social networks can serve as influences over producer's management decisions. As indicated in the innovation-diffusion paradigm: social learning, influence, and information transfer play roles in determining the rate of adoption of innovations, techniques, and conservation management practices (Upadhyay et al., 2003). Social networks play an important role in the diffusion of information and the adoption or removal of agricultural innovations, technologies and management practices (Maertens and Barrett, 2012). Conley and Udry (2010) found that farmers adjusted their inputs to align with information from their neighbours who had experienced prior success with the change in production. Social networking and social learning is a possible influence on the adoption or removal of shelterbelts and might be important to consider in extension and policy activities.

4.3.3 Producers Financial and Land Tenure Conditions

Another factor that could influence decisions related to the adoption or removal of shelterbelts on the prairies is the financial situation of producers. Suri (2011) indicated that the financial situation of farmers may act as a barrier to adoption due to the high front-end investment in the new technology, technique, or management strategy. Similarly, Davey and Furtan (2008) indicated that total farm sales was a significant factor in determining producers' decision to adopt zero till or not; with producers with higher total average sales being more likely to adopt the new technology (Davey and Furtan, 2008). The recent changes in policy have resulted in an increased cost associated with shelterbelt implementation. The higher costs associated with purchasing, maintaining, and dedicating land to shelterbelts may act as a potential barrier, particularly to low income producers, when it comes to increasing shelterbelts on the prairies; however, if the trend is towards removal, larger firms will be more likely to participate in this trend and encourage others to also participate in removal activities.

Land tenure is another potential influence or barrier to adoption of shelterbelts. In the 2011 agricultural census an average of 1,234 acres is being reported as rented (Statistics Canada, 2012a). This poses potential concern for the long-term management and adoption of shelterbelts as rented land may not be managed with long term sustainability in mind. Fraser (2004) found that farmers who own their own land tend to manage it more for the long-term sustainability of their lands and tended to include perennial crops in their rotations/management than those in rental agreements. He also found that length of tenure had little impact on the presence of perennial crops such as shelterbelts (Fraser, 2004). This trend could pose as a potential barrier or challenge for future shelterbelt management and retention strategies as there is a significant amount of rented land, 42%, in Saskatchewan. In addition to this immediate concern, land that is rented out may be more likely to be sold to larger crop production operations which, as was identified in this study, are the most likely to remove shelterbelts. This transfer from current small holders to large operations could potentially result in further removal.

4.4 Summary

Many factors impact the management decisions of producers, including: their world view, goals, values, perceptions, social networks, financial situation, and land tenure situation. This is not an exclusive list of the factors that can act as influences or barriers to adoption but these are some of the types of considerations that have been examined by previous studies related to agricultural adoption (particularly that related to zero or low till management). External influences, producer participation, and personal preference are often a part of a producers management decisions. It is difficult to measure the degree or extent that each factor plays in management decisions. It could be theorized that farmyards with established trees would be worth more than unestablished yards chiefly for the benefits they would provide the resident (Kulshrestha and Knopf, 2003) as long as the cite will be used for a yard or residence. By including stakeholder (producer) perspective in the data collection, a more robust understanding of what factors influence shelterbelt management, adoption, retention and removal can be achieved. When considering the benefits associated with shelterbelts, option value, and property value benefits are going to be context-dependent but impact on land and resale value should be considered.

Chapter 5: Survey Design and Evaluation

5.1 Introduction

A survey was selected as the method of data collection for this research on farmer's opinions, thoughts, and values related to shelterbelts as a part of agricultural production. The survey questions were created with the literature review and current policies in mind. Various potential factors related to the market and non-market costs and benefits, including areas such as environmental, social, agronomic, political, and economic spectrums, were included in the survey questions. The surveys were conducted in the summer of 2013 through on-farm visits (in conjunction with AGGP research), phone calls, and meeting producers at agricultural events. This chapter will cover the survey design and evaluation of the survey as compared to the population.

5.2 Sample Selection

Potential survey participants were selected using the participants who had been randomly selected and agreed to participate in the AAGP shelterbelt research. These participants were selected using tree order records from 1925 to 2009 from the Indian Head shelterbelt center. With the tree orders the legal land locations and tree species were provided were used for mapping and sorting purposes. These legal lands were mapped and then overlaid with a cluster of agricultural Eco districts and soil zones. From this the clusters with highest amounts of shelterbelt trees for each species were identified. A group of sampling sites were selected around this cluster. In addition, other sites were randomly selected in order to provide validation information for the information collected from the clusters. The initial sample selection was set up for the AGGP research on greenhouse gases in shelterbelts. The surveys were conducted at a variety of the initial main cluster and validation sites for the various tree species included in the AGGP research. The locations were picked from the cluster analysis by identifying which townships the clusters or sites were in and calling registered land owners until willing participants were identified. It is at these sites where the farm call surveys were completed during the field season of 2013.

5.3 Survey Design

The survey consisted of several parts which addressed various facets related to shelterbelts and their management. A combination of multiple choice, yes/no, Likert-Scale Ranking questions, and open-ended questions were used. The survey was divided into three main sections which collected information on 1) the farm operations, 2) shelterbelt management information and opinions, and 3) farm operator information. The goal of the survey was to identify factors that influence producers' management decisions related to shelterbelts as well as to understand and examine trends that may be happening related to shelterbelt management. The survey sample was randomly selected from all areas of the agricultural region of Saskatchewan in conjunction with the Agriculture and Agri-Food Greenhouse Gas Program (AGGP).

5.3.1 Questionnaire and Question Format

The questions included in the survey were drawn up in consideration of a wide variety of the aforementioned costs and benefits associated with shelterbelts in prairie agricultural systems. Several types and styles of questions were included in the questionnaire which is presented in Appendix I**.** The survey included descriptive information on the farm (i.e., acreage) and the producer, a combination of multiple choice and open questions related to shelterbelts on the farm, Likert-Scale ranking questions of costs and benefits of shelterbelts, an open question related to current shelterbelt policy changes, as well as several open questions specifically related to private costs and benefits. It was not possible, due to time constraints, to include every possible cost and benefit associated with shelterbelt use and management; therefore, the open questions related to costs and benefits were included so that producers could indicate any of the costs and benefits that they perceive related to their shelterbelts.

5.3.2 Survey Administration

Surveys were conducted in the summer of 2013. There were 61 collected surveys in total: 59 from Saskatchewan and 2 from Alberta (near Lloydminster). In fact, a total of 110 surveys were handed out in person at on-farm visits, at farmer educational events (i.e., Conservation Field Day), and through snowball sampling techniques (i.e., neighbour/brother stopping in while during a farm visit).

Overall, participants were more willing to share knowledge and discuss shelterbelts in person. If they did not have time during such visits, the questionnaire was left with them or a family member to be completed at a later time and sent in by mail (postage provided). Using this approach, the response rate was nearly 100% when the producer had time to go through the survey with the researcher, with only one producer declining to participate in the survey even though he had time. The return rate dropped significantly when the producer did not have time to go through the survey with the researcher during the farm visit. This is evident in the 55% return rate for the total study.

5.4 Survey Evaluation

The survey was a small sample of agricultural producers and landowners in the province of Saskatchewan. Since the survey was a small, random sample it was compared to Statistics Canada 2011 census data of farms and farm operators. The 2011 census is the most recent census data available (Statistics Canada, 2012b). In the survey, information was collected on variables that were reported in the 2011 agricultural census. The means of the sample and the census data were compared. The census is representative of the population as it is completed by all producers for specific details on their farm and operations. Variables for both farms and farm operators for this comparison included gender, age, education level, years farming, farm type, farm size, rented land, organic production, and farm income.

For the purposes of this research the population is considered to be farmers within the province of Saskatchewan. Although there were two producers from Alberta, they were located in close proximity to Lloydminster, near the border of Saskatchewan and Alberta. In addition, the Soil Zones/ecozones extend beyond the boundaries of the Saskatchewan border into Alberta, making the two sites outside of Saskatchewan similar in nature to those in agricultural regions of Saskatchewan. To show that the sample was representative of Saskatchewan as a whole, it was compared with the Statistics Canada 2011 Agricultural Census Farm and Farm Operator Data for the province of Saskatchewan (Statistics Canada, 2012a). The Statistics Canada data did not include all of the variables related to demographics that were collected in the survey but the ones that were common to both were used as a comparative measure to determine if the random sample was representative of the population.

5.4.1 Farm Operator Demographic Data

In the survey there was a section dedicated to collecting specific information on the individual who was participating in the survey. The personal demographic data collected in this section of the survey included questions that required participants to indicate their gender, age, level of education, and number of years farming/experience. Sections 5.2.1 to 5.2.4 inclusive describe the demographics of producers included in the survey sample as compared to the 2011 Statistics Canada farm operator data.

5.4.1.1 Gender

In the sample, 24.6% participants were female and 75.4% participants were male. Numbers from the 2011 Canadian Census data show that 22.9% of farm operators are female and 77.1% of farm operators are male (Statistics Canada, 2012b). Figure 1 shows the visual comparison of the percentage of male and female farm operators in the 2011 census and the 2013 shelterbelts survey sample. Based on this compassion this sample is deemed to be comparable to

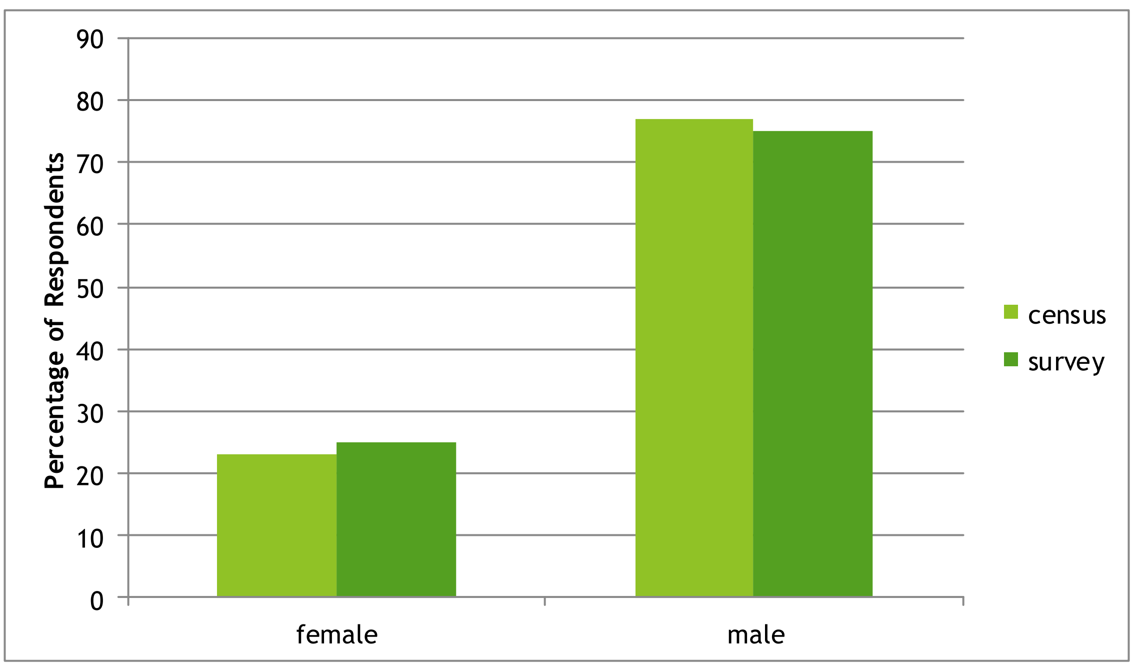

FIGURE 1- ILLISTRATES THE COMPARISON BETWEEN GENDER IDENTIFICATION IN THE 2011 CENSUS (LEFT) AND 2013 SURVEY SAMPLE (RIGHT)

comparison of the percentage of male and female farm operators in the 2011 census and the 2013 shelterbelts the gender representation in this specific population.

5.4.1.2 Age

A population pyramid, shown in Figure 2, for the sample was constructed to help visualize the samples age and age range by gender. The population pyramid highlights that within the sample, the sample population had a high proportion of middle age to elderly males with considerably less young males and less females of all ages. The age range of farm operators included in the 2011 census data was not grouped by gender; therefore, to compare with the sample data the mean of the entire samples age was compared. The age range of participants in the study ranged from 23 to 87. The median age of the participants in the sample was 55. The mean age of the sample data was 55.2 years old, suggesting that it is very close to the average age reported in the 2011 Census Data (Statistics Canada, 2012b).

The Statistics Canada data are grouped by age category (and not gender and age categories). The sample was grouped into the same age category groups as the Statistics Canada census for further comparison. The percentage of participants within each of the Statistics Canada categories for age was similar. Statistics Canada (2011) data for Saskatchewan farmers shows that 9% of farmers were under 35 years of age, 42 % are between 35 to 54 years of age , and 49% of farmers fell into the 55 years and over category (Statistics Canada, 2012c). In this sample 15% of farmers were under 35, 31% were between 35 and 54 years of age, and 54% were over 55 years of age.

The proportions in each age group for this sample are comparable to that of the population and follow the same trend of the largest proportion of producers being over 55, followed by producers 35-55, with producers under 35 comprising the smallest proportion of producers. This indicates that both the sample's mean age and age group distributions is representative of the Saskatchewan farming population as a whole.

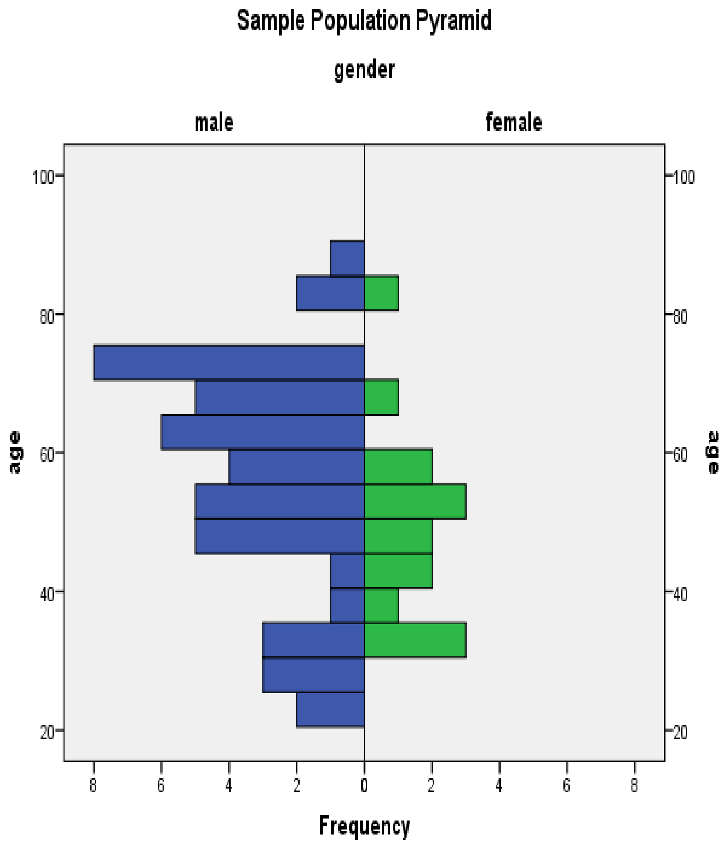

FIGURE 2- POPULATION PYRAMID SHOWING SAMPLE AGE DISTRIBUTION SAMPLE

5.4.1.3 Education Level

Education was another demographic variable that was collected in the survey. Unfortunately, there was no comparable measure in the Statistics Canada Census for this variable. Sample frequencies of responses were determined for each level of education and are shown in Figure 3. For the study sample, a high school education (10-12 years of school) was the most frequent response with 37.7% of survey belonging to this group. University and technical diploma levels of education were the next two highest categories with 26.2% and 23.0% of respondents belonging to these categories. Junior high education (7-9 years) of school was the lowest of all levels in the sample, with 13.1% of respondents reporting this level of education.

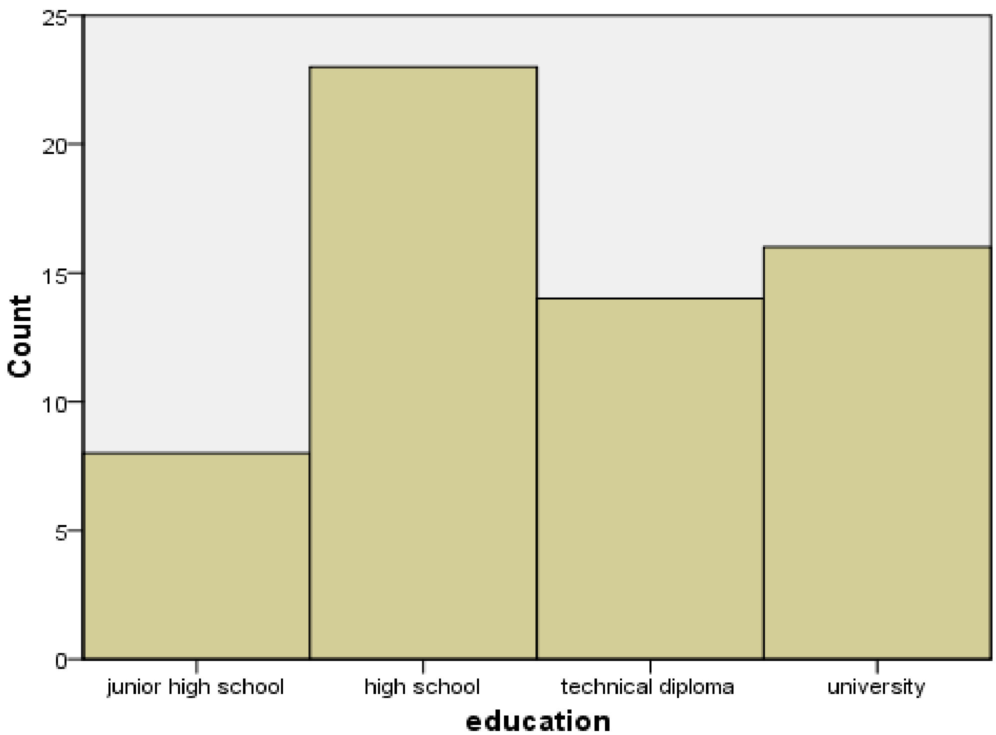

FIGURE 3- RESPONSE FREQUENCIES FOR EDUCATION LEVELS FOR THE SAMPLE

5.4.1.4 Years Farming

Years' farming (since the age of 18) was the last demographic related variable that was collected. Years' farming shows how long respondents have been involved in agriculture. This variable was included as a measure of how experienced each farmer was within the industry. In this sample, years of farming experience since the age of 18 ranged from less than 1 year to 63 years. The mean number of years farming experience was 30.56 with a standard deviation of 18.0. This variable is useful for understanding level of practical experience with topics related to agriculture and its management. There was no comparable measure within the Statistics Canada data comparison. Figure 4 shows a clustered bar chart of the age ranges of sample participants broken up by gender. Correlation analysis indicated that there is a high degree of correlation between age and years of farming experience (+0.77, which was significantly different from zero using a 2-tail test).

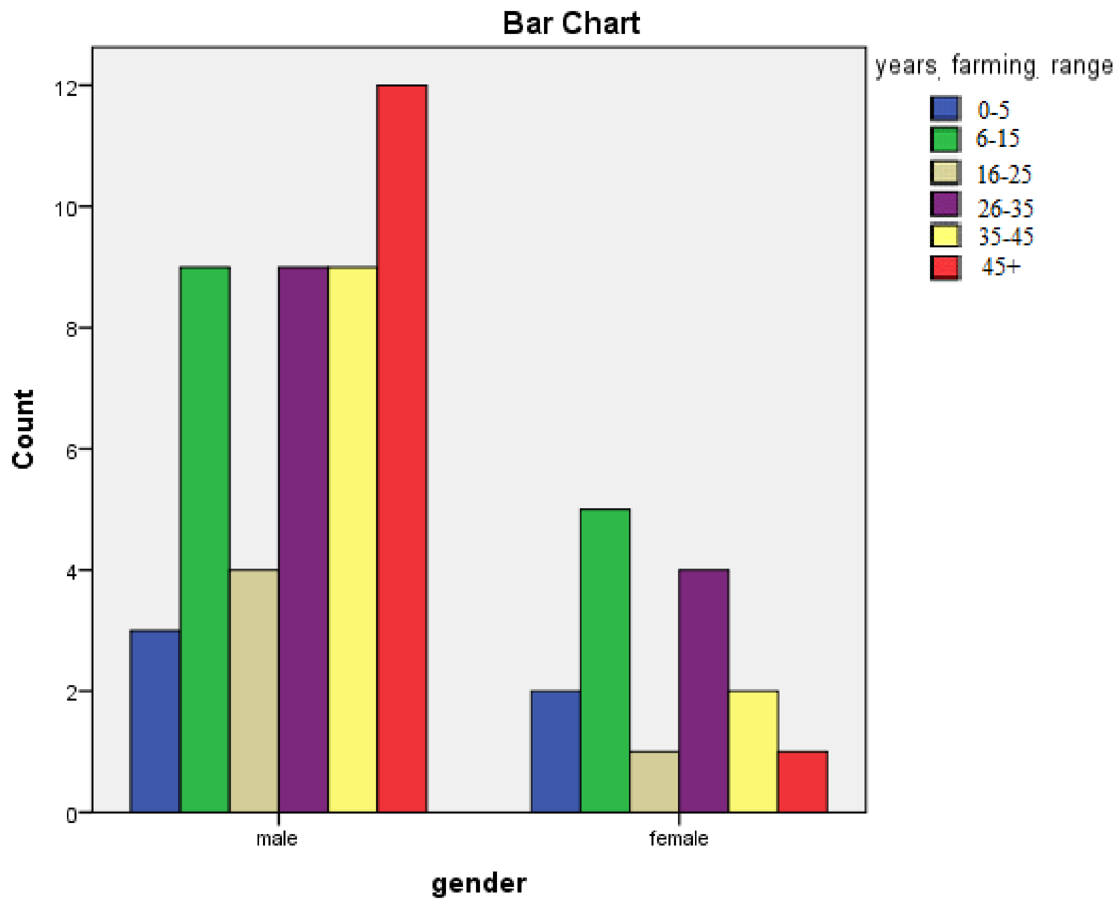

FIGURE 4- RESPONSES OF SAMPLE GROUPED BY YEARS OF FARMING EXPERIENCE AND GENDER

5.4.2 Farm Based Descriptive Data

In the survey, there was a section that asked specific questions related to the farm operation. The farm based characteristics collected in this section of the survey asked producers to indicate their farm operation type, farm size in acres, amount of land rented or leased from someone else, amount of land rented out to someone else, farm income, and legal land description (for mapping purposes). The next section describes these characteristics along with a comparison with the 2011 Statistics Canada farm data, where a valid comparison variable exists.

5.4.2.1 Operation or Landowner Type

Survey respondents were asked what type of operation or land owner they considered themselves. There were three main categories: crop, livestock, and mixed (crop *and* livestock production) as well as an "other" option with "please specify" section. The majority of respondents fell into the first three categories (crop, livestock, or mixed). In addition, two sub-categories – retired farmers, and land rented out to farmers, were also identified. There were some other farmers belonging to 'other' category. These operations included orchard, hobby farm (i.e., small acreage with horses or chickens) or tree nursery. Figure 5 shows that crop production enterprises were the most common type of operations in the sample (36.1%), followed by mixed operations (26.2%), livestock operations (15.1%), and retired and land rented out (16.7%), and other (5.0%).

The results found in the sample are consistent with the trends observed in the 2011 Agricultural Census. In the Census, crop production operations were the highest (60.1%), followed by cattle farms (20.2%) (Saskatchewan Ministry of Agriculuture, 2012). The census

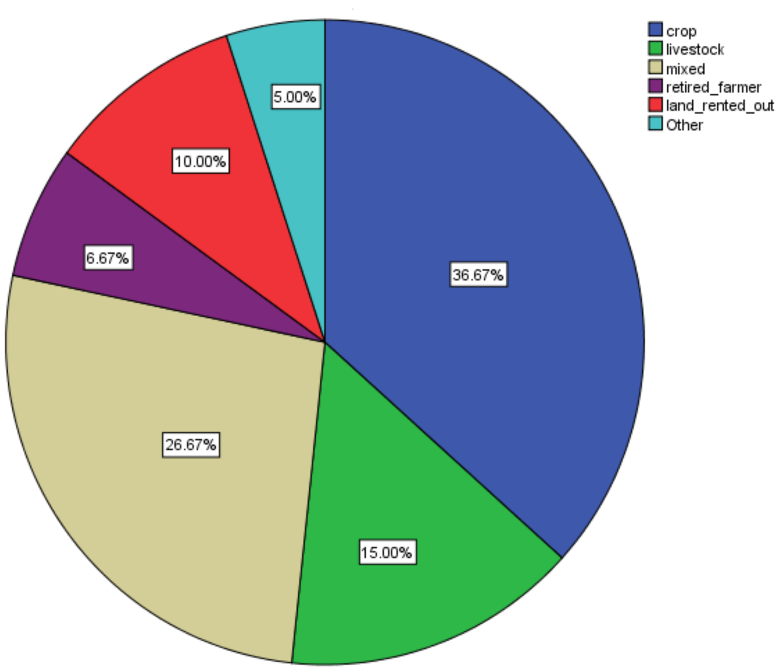

FIGURE 5- PERCENTAGE OF FARM TYPES REPRESENTED IN SAMPLE

did not specify mixed operations (that had both livestock and crop production)[7]. Overall, the trend is that crop production is the highest category of farms followed by livestock operations and this is consistent for the population within the province.

5.4.2.2 Farm Size

Participants were asked for their total farm size in acres[8], including rented or leased land, as one of the farm level characteristics. Farm size ranged from less than 160 acres to 18,000 acres when leased or rented acres were included. When rented or leased acres were not included in farm size calculations farms ranged from 0 to 11,000 acres. The mean size of sample farms with leased acres included was 2,380 acres with a median size of 950 acres. When leased or rented acres were not included the mean farm size fell to 1,718 acres with a median farm size of 720 acres. The mean farm size where rented or leased acres were not included is comparable to the value in the 2011 Census data. Statistics Canada reported that the mean farm size for Saskatchewan in 2011 was 1,668 acres and that it had increased 15.1% since 2006 (Statistics Canada, 2012d). This trend towards increased farm size could account for why the sample size had a slightly higher mean farm size of 1,718 acres than the census data.

Overall, the average farm size in the sample is to be similar to the provincial average. The mean farm size (in acres) at the time of the 2011 agricultural census was 1,668 acres (Statistics Canada, 2012e). This mean was used to divide the data into three sub categories for farm size: 1) small operations -- less than or equal to 640 acres, 2) mid-sized operations between 640 acres to 1960 acres (with the mean in the middle of this category), and 3) large operations those greater than 1960 acres[9].

Figure 6 illustrates the breakdown by farm size category of farm operations included in the sample. Operations less than 640 acres were the most common in the sample (being 43% of the total), followed by large operations at 34%. Medium scale operations comprised 23% of the

7 It should be noted that in the Census, farms are classified by source of income – a crop farm obtains 51% or higher income from crop production; however, income from specific sectors was not collected in the survey; therefore, our data cannot be stratified that way and the trend comparison was the closest comparison available to the sample data collected.

8 The Imperial measure of acres was chosen over the metric hectares as this is what Statistics Canada uses as well as what most farmers are comfortable with using.

9 1960 acres is not large in comparison to some of the largest farms (i.e. one farm in the sample was ~10,000 acres); however, it is based on the mean farm size indicated in the 2011 census

sample. The high amount of large farms is consistent with the trends identified in the 2011 census towards larger farms (Statistics Canada, 2012e). In addition, the mix of small farms, medium farms, and large farms in this sample was comparable to that of the 2011 Statistics Canada Census. Figure 7 shows a distribution by the farm size ranges in the 2011 census. In the

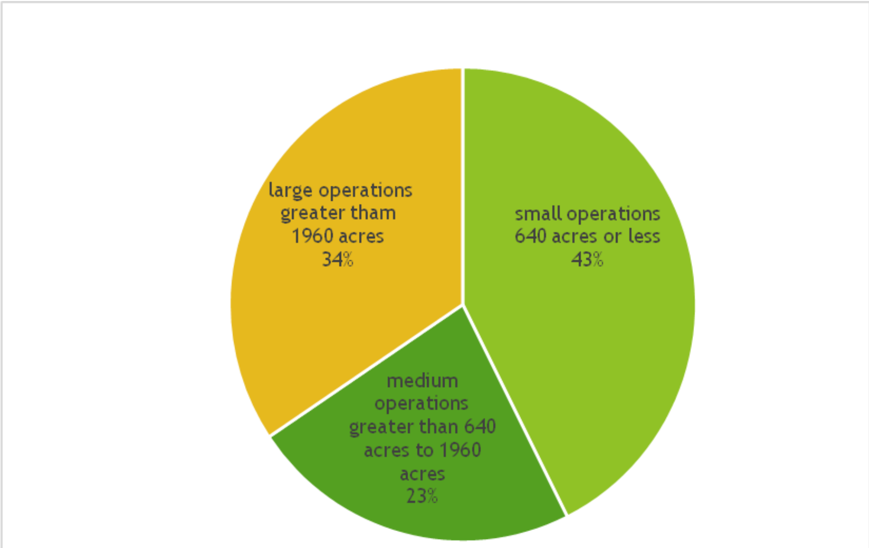

FIGURE 6- BREAKDOWN OF PERCENTAGE OF FARM SIZES CLASSIFIED AS LARGE, MEDIUM, AND SMALL OPERATIONS IN THE SAMPLE

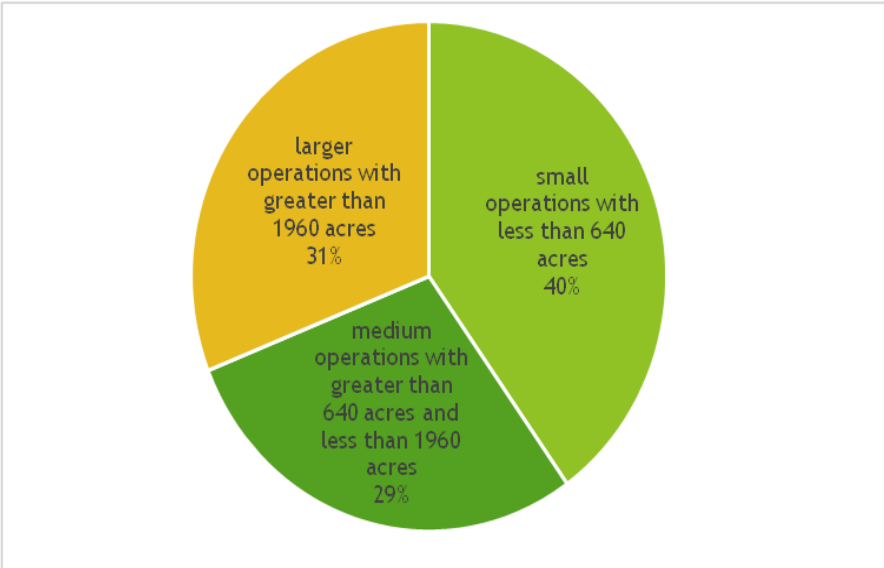

FIGURE 7- 2011 STATISTICS CANADA CENSUS DATA GROUPED BY FARM SIZE RANGE OF SMALL, MEDIUM, AND LARGE

census data small operations were the most common, followed by larger operations, and then medium operations. The mix of small, medium and large farms is comparable between the sample and the population.

5.4.2.3 Rented or Leased Land

Survey participants were asked how much land that they rented or leased from other land owners. Forty-four percent of respondents reported renting land from other land owners, such as private land owners, government, and other arrangements such as crop sharing. Farmers who reported renting acres from other land owners ranged from 60 rented acres to 7,000 rented acres. For farmers who rented land, the mean amount rented was 1,496 acres with a median of 640 acres. This substantial amount of acres being rented is consistent with the recent census data which reported that rented acres make up a substantial proportion of total farm areas in the 2006 census the mean of those who reported renting land was 1060 acres rented (Statistics Canada, 2012f). The mean amount in the sample was slightly higher at 1,496 acres of rented land than the 1060 reported in the census for Saskatchewan but this consistent with the trend of increasing rented land from 1991-2011 census years (Statistics Canada, 2012f).

5.4.2.4 Rented-Out Land

Farm related data were collected on number of acres being currently rented out or leased to another farmer/land manager. This characteristic was collected to determine if the participants were still actively farming. The mean amount of rented out land, indicated by those who were renting out their land, was 222 acres. Those who indicated they were renting out their land were renting out anywhere from 100 acres to 720 acres. The median amount of land rented out was 155 acres. This information, combined with the data collected and reviewed in the section above on amount of land rented, suggests that the farmers who are renting large amounts of land are renting from several land owners as most of those renting out their land are renting only small parcels out. There was no similar measure collected in the 2011 census.

5.4.2.5 Organic Production and Irrigation

Participants were asked if they had any organic production as a part of their operations. Organic hay for livestock on farm, non-certified organic production, transitional organic production, and certified organic production were all included in the category of organic production for the purposes of this survey. Thirteen percent of participants indicated having some level of organic production on their farm. This number is significantly higher than the provincial average reported in the 2011 census, which was 2.9% of the total number of producers (Statistics Canada, 2012g). This could be an indicator that shelterbelts are considered more important for success of organic operations. It could also be related to broader definition of organic operations used in this survey. In addition to these factors, the higher importance of shelterbelts for organic agricultural production should be noted. Organic producers use tillage to control weeds in their operations and as a result they are more dependent on management techniques such as shelterbelts for erosion mitigation and moisture management. This higher reliance on shelterbelts may have resulted in the higher response rate from organic producers.

Information was also collected related to the use of irrigation on the farm. This was a yes/no question. Of the total, 3.3% respondents indicated having irrigated acres and 96.7% indicated no irrigated acres. In the 2011 census 1.4% of farms in Saskatchewan reported having irrigated acres and/or irrigation equipment (Statistics Canada, 2011). The survey proportion is slightly higher but comparable to the census data. One of the farms that reported irrigation was a very large commercial crop production operation (over 10,000 owned acres) and the other was a specialty operation with an orchard.

5.4.2.6 Farm Income

Farm income data was collected by asking participants to place their gross farm sales within pre-determined income range bins. This question was considered to be a more sensitive topic and to increase the willingness of respondents to offer this information pre-determined bin ranges were used. Some, 8%, of respondents opted to not participate in this question. Of those who answered the question, 39% indicated making a gross income over $150,000. This was followed by those who indicated a gross income of less than $30,000 (with 32% of those who answered the question). The remaining 29% were in-between the extremes and indicated gross farm income between $30,000 and $149,999. Figure 8 shows the breakdown of responses for the income bins included in the survey. This graph highlights the income disparity within the industry.

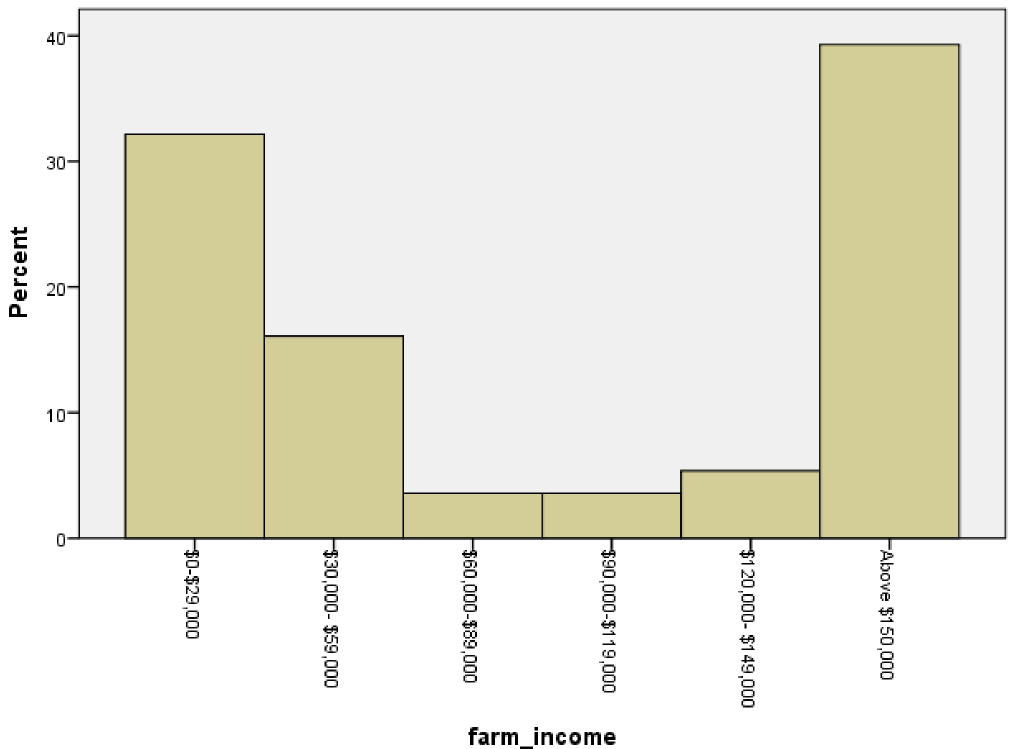

FIGURE 8-GROSS INCOME OF FARM OPERATIONS REPORTED AS PERCENTAGE OF THOSE REPORTING

5.4.2.7 Legal Land Description

The legal land description of each operation was collected in the survey. This information was used to classify the Soil Zone, ecozone (sub continental level, describes larger ecosystems) and ecoregion (distinctive communities, set apart by climatic or landform factors) (Secoy, 2012) of each farm as well as for mapping purposes. Figure 9 shows the location of the operations of those who participated in the survey, on a map of Saskatchewan with the various ecoregions and the physical location of participant's farm operation/land tenure. These locations were mapped using the legal land descriptions provided in the surveys by participants.

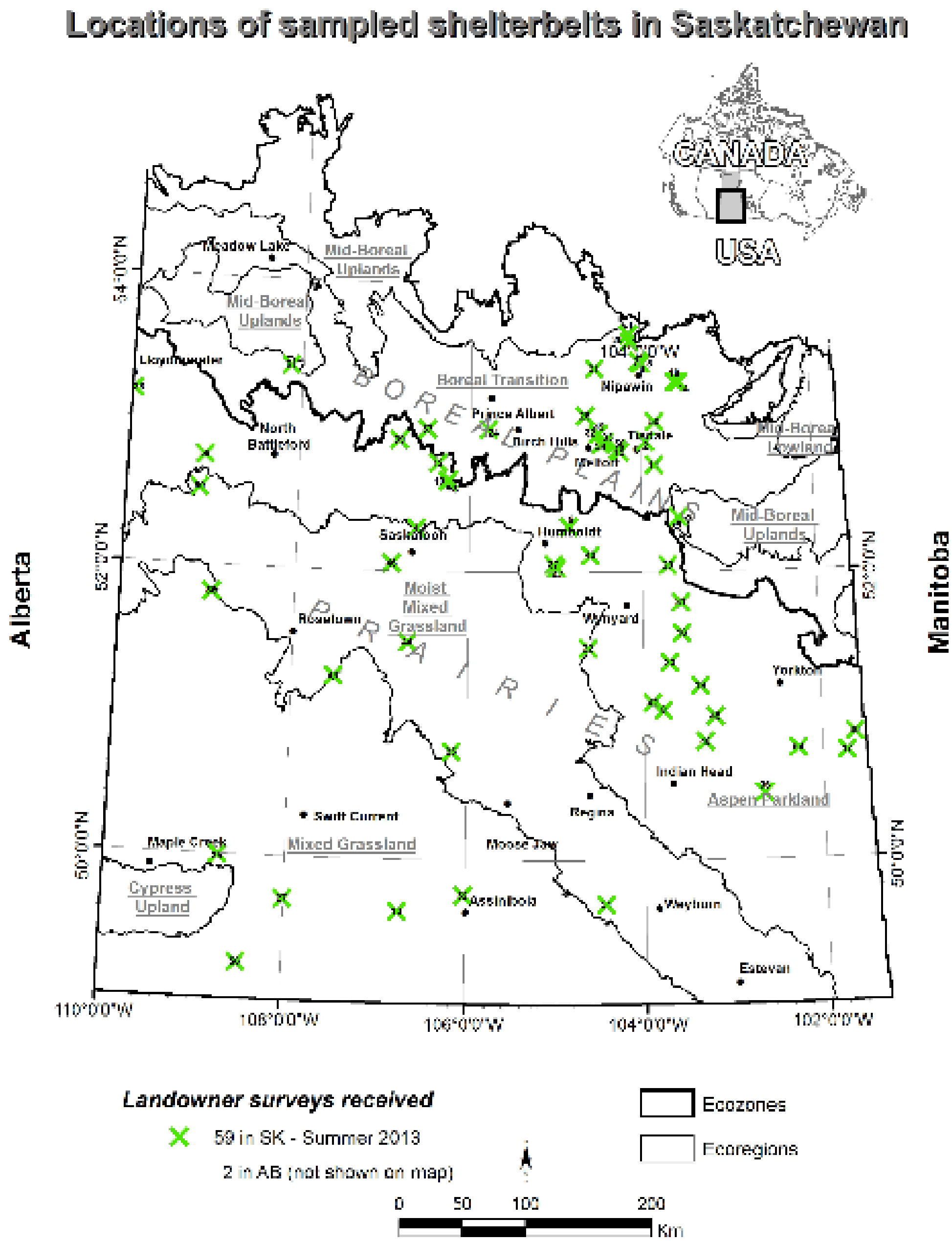

FIGURE 9-LOCATIONS OF SAMPLED SHELTERBELTS IN SASKATCHEWAN (AMICHEV, 2013)

5.5 Summary

The survey distribution and data collection took place through farm calls, over the phone, and at events for producers in the summer of 2013. The sample was collected through a combination of random sampling techniques (majority) and snowball sampling. The sample included 61 individuals from all over the province of Saskatchewan including two producers from the province of Alberta. The survey included a variety of question types and categories related to farms, farmers, and shelterbelts.

The sample collected in this survey was deemed to be representative of the population based on a comparison with the 2011 Statistics Canada farm and farm operator data. This comparison suggested that the sample farms were similar in terms of size, type of operations, and amount of rented acres. From the comparison of both the personal demographic and farm level characteristics in the sample with the Census data, it was concluded that the sample is representative of the population of agricultural producers in Saskatchewan. The industry is dominated by males over the age of 50 and this is similar to the participants included in the random sample for this research. The similarity of the sample to the population data strengthens the conclusions that will be drawn from this study.

Chapter 6: Data Analysis and Results

6.1 Introduction

The survey data were analyzed using several techniques including: descriptive statistical analysis, frequency analysis, and bivariate correlation analysis. Due to length of the survey and the amount and variety of data collected, use of several techniques was necessitated. The open questions were coded so that the responses could be grouped into categories for further analysis. In addition, descriptive statistics analysis, frequency analysis, and correlation analysis were conducted using the SPSS 21 statistical package. The focus of the analysis was to identify the economic, and non-economic factors that influence producer's decisions related to shelterbelts as well as to identify if different factors were important to different types of producers. This section provides details on descriptive statistical analysis, coding of open responses, and correlation analysis.

First all of the surveys were analyzed as one group of producers to give a baseline for later comparisons of sub-groups. The sample was then broken down into sub-groups by the factors or demographic related characteristics identified as important factors influencing shelterbelt management decisions. The similarities and differences within these sub-groups as compared to the entire sample were used to make inferences on what possible factors could be influencing the management decisions related to shelterbelt adoption or removal on the prairies as a whole and even more specifically within the various factor related sub-groups. This type of approach to analysis was used to gain insight into the major factors that are influencing various producers in regards to their management decisions surrounding shelterbelts.

6.2 Survey Analysis

Frequency analysis was conducted for all of the questions (excluding the open questions) in order to determine the mean response as well as to identify how many producers responded to various choices in each question. This provided valuable information on each question including: the most popular, least popular, and mean response. Frequency analysis was also used within different groups of questions. This section focuses on the questions that had discrete responses (open response questions presented in Section 6.2.4 Description of Costs and Benefits Identified by Producers). In this section the data have been broken into five categories based on the topic or style of questions. (1) Section 6.2.1 includes analysis of questions related to farm operator and farm specific information, (2) Section 6.2.2 looks at questions specifically related to shelterbelts; (3) Section 6.2.3 contains the questions that were delivered using a Likert-Scale to rank factors related to shelterbelt management, (4) Section 6.2.4 covers the costs and benefits identified by survey participants that were not included in the Likert Scale rankings, and (5) Section 6.2.5 which includes Bivariate Correlation Analysis presented in a mind-map A mind-map is a way to visually represent how people think about how things are related/interact using correlation analysis. A summary of the results of the survey can be found in Appendix B- Survey Results for Sample.

6.2.1 Descriptive Statistical Analysis

Descriptive statistical analysis was done on the questions that related to demographic data for the farm operator and farm characteristics. For each variable the following measures were selected: maximum, minimum, mean, and standard deviation. For the continuous variables, such as age, years farming, farm size, farm land rented, land rented out, and average age of shelterbelts this analysis provided information that was useful to understanding the sample characteristics. Table 1 provides a summary of the descriptive statistics for the farm operators' demographic data.

TABLE 1- DESCRIPTIVE STATISTICS FOR CONTINUOUS VARIABLES

	Unit of Measure	N	Minimum	Maximum	Mean	Std. Deviation
Age	Years	61	23	87	55.18	16.066
Years farming	Years	61	0	63	30.56	18.013
Farm size	Acres	61	5	18000	2380.62	3261.718
Rented or Leased Land	Acres	60	0	7000	673.17	1381.629
Land Rented or Leased Out	Acres	61	0	720	36.31	108.451
Shelterbelt average age	Years	58	4	118	37.87	23.115
Valid N (listwise[10])		57				

[10] Valid N (listwise) is the number of non-missing values

Understanding the characteristics of the sample in this way helps to better understand some factors at play within the survey sample. Table 1 shows that within the sample there is variation as many of the variables had large ranges. In this sample a wide range for age, farm size, years of farming experience, and shelterbelt age was estimated. This variation provides an indication of the breadth of farm size and composition, farm operators, and shelterbelts present in the province and included in this sample. This variability in the type of producers and shelterbelts is necessary for identifying potential barriers to adoption, among others.

6.2.2 Shelterbelt Type Related Specific Questions

Some of the questions in the survey were designed to specifically answer questions related to views or perceptions related to shelterbelts in general as well as to identify various features associated with the specific shelterbelts on the farm such as tree species, shelterbelt lengths, and shelterbelt ages. These questions provided some insight into the variety of shelterbelts that exist on the prairies and the attitudes related to shelterbelt benefits, costs, and retention. One of the questions asked in the multiple choice section had respondents indicate what type of shelterbelts were currently present on the farm operation. The types of shelterbelts that were included in this question included: farmyard, field, livestock, and other (i.e., natural buffer strips, riparian belts). The remainder of this section presents the results by shelterbelt type groups.

6.2.2.1 Farmyard Shelterbelts

Farmyard shelterbelts are the most commonly indicated type of shelterbelt by agricultural producers and landowners. In fact, 98% of respondents indicated that they had farmyard shelterbelts with the other 2% indicating "other" shelterbelts around their home[11]. This indicates the significant importance that farmyard shelterbelts play in the homesteads of prairie producers.

[11] Other types of shelterbelts indicated around farmyards included naturally occurring trees. The 2% who indicated other shelterbelts were located at the Northern Boundary of Saskatchewan agriculture and there homes were established in forested regions so they had not planted or maintained shelterbelt specific trees and designated the trees around their homes in the "other: category.

There were many comments about the importance of farmyard shelterbelts for quality of life of producers and landowners. Respondents indicated in regards to their farmyard shelterbelt that:

> "Trees make life worth living and much more enjoyable" (Male participant, 55 years old and over)
>
> "I love my farm[yard] shelterbelts. They make the country look so much better. I don't understand anyone in this country who doesn't have a shelterbelt around their yard" (Male participant, 35-54 years old).
>
> "A tree is a special thing you just need them." (Female, over 55 years old, retired)

These sentiments were a reoccurring and unifying theme that farmyard shelterbelts are an essential part of life on the prairie homestead. This theme was also noted across all areas of the province for all types of operations. Respondents indicated and agreed on the high value that is placed on farmyard shelterbelts for quality of life and wellbeing. This indicates that farmyard shelterbelts are adopted and maintained based on the principles of the utility paradigm whereby producers and landowners gain a great deal of utility and satisfaction from having farmyard shelterbelts.

Producers and landowners were very proud (based on comments made and amount of time spent on maintenance) of their farmyard shelterbelts and the high degree of value placed on as illustrated by all producers and land owners having some form of shelterbelts around their yard (natural 2% or planted 98%). This is further supported by the high ranking of the Likert-Scale factors related specifically to farmyard shelterbelts as covered in section 6.2.3.3 Farmyard Shelterbelts Likert-Scale Questions. Based on this, farmyard shelterbelts are and will continue to be an important part of life for those living in rural areas. People living in rural areas indicated that they will most likely continue to adopt and retain shelterbelts around their farmyards for the high degree of personal (private) benefits that they receive from these shelterbelts. However, with less and less people living in rural areas in the future, the amount of farmyards with shelterbelts may decrease, which could be a concern for the overall landscape level benefits that these shelterbelts collectively provide. In addition, to less new farmyard establishment, farms are continuing to increase in size (Corman, 2003; Cushon, 2003) and this will continue to impose challenges for future shelterbelt adoption and retention.

6.2.2.2 Field Shelterbelts

Next to farmyard shelterbelts, field shelterbelts were the most common with 30% of producers indicating having field shelterbelts. Many producers indicated that field shelterbelts had been planted as a direct result of programs and policies related to shelterbelts and soil protection. For example producers mentioned the "Save our Soils Program", provision of R.M. (rural municipality) tree planters, the PFRA free trees, extension services and even local groups, like snow plow clubs[12], and community tree planting days as having impact or influence on the planting of field shelterbelts. These types of programs, policies, and initiatives were effective as they provided education and awareness about the benefits of shelterbelts (i.e., soil conservation) as well as helped to reduce the costs associated with shelterbelt adoption specifically through the provision of free trees and reduced labour costs (i.e., tree planter, community planting days). The cost of trees and labour requirements are two of the most commonly indicated cost barriers faced by landowners. Overall, many producers pointed to past programs as motivators for planting and changes in agriculture production practices as motivators for removal. One producer summarized it as:

> "Some of the costs [of our field shelterbelts] were offset by [the] Save Our Soils Program. In today's advancement of farm technology … shelterbelts have a less positive affect on crop management. With the size of today's equipment shelterbelts can have a negative effect [due to] overlapping." (Male producer, 35-54 years old)

This comment was similar to those made by other producers who had at one time planted shelterbelts and were now removing or considering removing shelterbelts. A common theme related to field shelterbelt was that changes in agricultural production has resulted in less benefit from field shelterbelts. This could be a significant barrier to future adoption and retention of field shelterbelts. In addition, this highlights that the larger the farming operation and large equipment the greater the cost that is imposed by shelterbelts in the form of reduced efficiency through increased time in fields and increased costs for inputs (i.e. seed, fertilizer, herbicides) required due to overlap around trees.

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[12] Several producers indicated that they were a part of clubs that coordinated the plowing and removal of snow in their rural municipality and that these clubs coordinated and encouraged the planting of trees (particularly carrigannas) to manage drifting snow.

6.2.2.3 Livestock Shelterbelts

Livestock shelterbelts did not comprise as large a proportion of shelterbelts as either farmyard or field shelterbelts. Only 24% of respondents indicated having livestock shelterbelts in their operations. Producers indicated that the benefits to the livestock from the shelterbelts, such as improved feed use efficiency, were important (as covered in the Likert Scale Ranking Section 6.2.3.2 Livestock Shelterbelts Likert-Scale Questions) but that the additional costs of maintaining the shelterbelts and minimizing livestock damage to the shelterbelts could be a potential barrier to adoption associated with shelterbelts specifically for livestock. Some comments related to the additional costs associated with natural shelterbelts in livestock operations included:

> "Our livestock shelterbelts provide shelter for our cows and habitat for wildlife. The one major cost associated with these is that they trap snow around the fence and we need to repair the fence. If we don't have a fence between the shelterbelt and the cows, the cows will destroy the shelterbelts over time." (Male participant, 35-54 years of age)

> "We have let the natural forest come-in in places and we do this by fencing the livestock out. Natural reforestation has been the main source of "renovation." Additional costs include fencing of approximately $400/mile to keep cattle from killing the trees." (Male participant, 55 years old and older)

These comments indicate that fencing costs for reducing livestock's negative impact on shelterbelts is a major cost borne by the producer.

6.2.2.4 Other Shelterbelts including Natural and Riparian Shelterbelts

The category of "other" shelterbelts included in this question was related to other types of shelterbelts including, but not limited to, riparian and natural shelterbelts. About 26% of producers indicated having some type of "other" shelterbelt on their farm. Many of those who had "other" types of shelterbelts indicated that natural shelterbelts, or natural reforestation of strips between fields, as the other type of shelterbelt present within their operation. Several comments identified the low maintenance associated with use of the natural shelterbelts as a major benefit of keeping them as opposed to planting new shelterbelts. Some of these comments included:

"The field shelterbelts on our farm are naturally occurring trees that were left as shelterbelts between fields when the land was cleared. There is no maintenance these shelterbelts they are natural." (Male, 55 years and older)

"We currently have many natural shelterbelts on our land therefore we don't need to plant any." (Male, under 35 years old)

The benefits of including natural shelterbelts in operations extend beyond the cost saving measures, such as reducing planting and maintenance cost,) indicated by this group into other areas such as discussed in the ecological goods and services sections 2.3. This type of cost saving principle is related to the income paradigm as producers are able to save time and money on planting/maintenance but still receive the benefits of shelterbelts and biodiversity within their operations.

6.2.2.5 Non Adopters of Shelterbelts (excluding farmyard)

In addition to producers with farmyard, field, livestock, and other types of shelterbelts, there were some sample producers with no shelterbelts (excluding farmyard), and some others with no shelterbelts at all. Figure 10 shows a Venn diagram of sample farms with distribution of various types of shelterbelts (excluding farmyard shelterbelts as all producers indicated some type of farmyard shelterbelts). This figure was developed using the answers to the question 10.b in the survey, which had respondents check off which type of shelterbelts they have in their operations. The responses were then sorted by participant and the types of shelterbelts they had on their farms. Excluding farmyard shelterbelts, 33% of respondents indicated having no shelterbelts on their operations.

Producers having no shelterbelts identified a variety of costs associated with shelterbelts. One producer expressed a variety of the costs (that were also identified by many of other producers) as shown in the following statement:

"Shelterbelts concentrates pesticide spray drift on downwind side. Shelterbelts cause salinity... [Shelterbelts] are only good around [the] house and yard and for animal shelter. They make crops prone to lodging and produce snowbanks that delay seeding. Grass works better to protect water ways [than shelterbelts] as leaves create algae… Shelterbelts are usually where grasshoppers lay their eggs and then move into crop to eat. Shelterbelts negatively influence land values for cropping [operations]… costs are greater than benefits for field shelterbelts. Shelterbelts need continual maintenance to be useful. [Today] air drills are the way farmers seed…and they are around 70 feet in length and the sprayer is 120 feet so tree rows in the field are a nuisance and a hazard..” (Female producer, 35-54 years of age).

These types of negative impacts were frequently identified by both those who indicated plans for active removal of shelterbelts as well as by those that indicated that they did not have any shelterbelts (other than farmyard) in their operations. In addition, 53% of agricultural operations who indicated no shelterbelts (other than farmyard) in their operation were crop producers which indicates that many of the negative impacts of shelterbelts are associated with crop production systems. This group of producers seems to follow the guiding principles of the income paradigm as they do not see a direct economic (income) related benefit to shelterbelts within their operations, only negative economic or production impacts, which prompts them to not include shelterbelts within their operations.

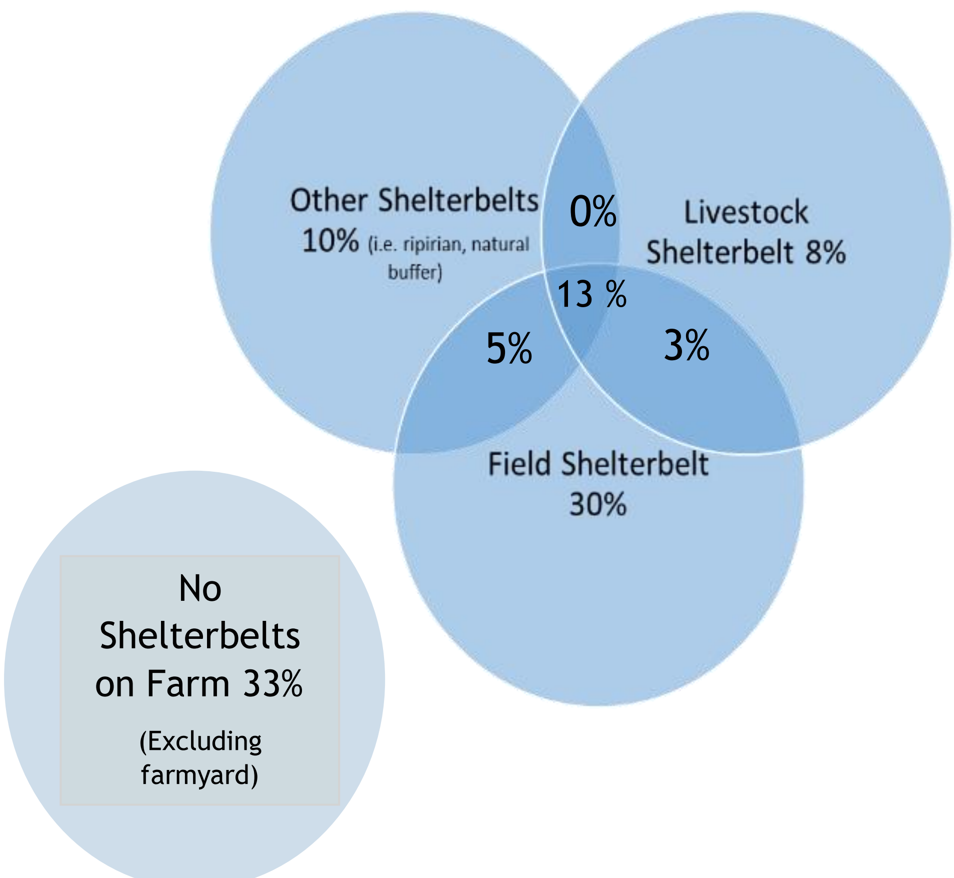

FIGURE 10- VENN DIAGRAM OF SHELTERBELTS TYPES (OTHER THAN FARMYARD SHELTERBELTS) EXPRESSED IN PERCENT OF RESPONSE PER CATEGORY

6.2.2.6 Multiple Shelterbelt Adopters (excluding farmyard)

The final group of producers consisted of who adopted multiple types of shelterbelts. Figure 10 shows the various types of multiple adopters in the sections of the Venn diagram that intersect between two or three categories. This group included 21% of all respondents in the sample, with 13% of respondents indicating that they had all types of shelterbelts in their operation (other, livestock, and field). This group included producers with mixed or livestock operations only and did not include any from crop production or "other" categories. In addition, of those who indicated the presence of multiple types of shelterbelts on farm (21% of the sample), 62% of these were organic producers. Within the entire sample population only 13% of producers indicated having organic production on their farms so this sub-sample represents a large proportion of all organic producers. This sub-sample of producers tended to comment on the importance of environmental and ecological factors. Some of the comments related to the importance or ecological significance of shelterbelts both for their operations and the landscape as a whole included:

> "[Shelterbelts provide] huge environmental protection in the farmyard and field. Crop increases of yields of 30+%, for organic production the shelterbelts are very important. Reducing soil erosion is the main reason for my field belts. Carbon sequestration is an extra bonus of shelterbelts." (Male, age 55 and over)

> "There should be a law if you take out trees then you should plant them somewhere else in a more convenient place. Trees are really important for the environment." (Female, 35-54 years of age)

In addition, this group as a whole tended to identify multiple uses for their shelterbelts including harvesting firewood for personal use or resale, hunting, collecting berries and mushrooms. Some of the comments related to non-agricultural uses by this group included:

> "I do enjoy hunting and eating berries from the trees around my home." (Male, under 35 years of age)

> "Firewood and some berries are additional benefits of shelterbelts." (Male, under 35 years of age)

> "Benefits include erosion control… We have about 1.2 a mile of native shelterbelts [naturally occurring trees] with berries that I really enjoy.... Shelterbelts [are good for] for wood. We chop some up and take it into a lady in town who has a wood stove and she likes that a lot." (Male, age 55 and over)

These producers are more closely following the principles of the utility and innovation diffusion paradigms than some of the other sub-groups. The group displays some of the characteristics of early innovators/adopters within the innovation diffusion paradigm as they made a decision to reject common agricultural practices and are implementing organic production. As discussed in Section 4.2.2. "[t]he innovation diffusion theory argues that communication, information, and influence alter the behavior of individuals within social networks (Wejnert, 2002). This paradigm suggests that adoption will occur by the majority as they see the success of the early adopters and innovators" (Section 4.2.2 this thesis). Organic production, production without pesticides or manufactured fertilizers, is very different than current production schemes that are highly dependent on pesticides and manufactured fertilizers (Cushon, 2003). In addition, to these characteristics this group indicated a variety of ways that they are able to get additional benefit or utility from their shelterbelts through multiple use. By including a broader spectrum of positive impacts in their decision making process related to shelterbelts, this group is aware of and valuing a wider definition of shelterbelt benefits and their function within agricultural ecosystems.

6.2.3 Likert-Scale Ranking Questions

The sample producers rank factors associated with shelterbelts impacts on their operations using the Likert-Scale ranking. The factors were ranked using five categories: highly negative (1), negative (2), neutral (3), positive (4), and highly positive (5). Appendix II, Part I includes all of the response frequency analysis including mean, standard deviation, and number of participants per question. Analysis of the response frequency and mean responses led to several noteworthy observations. There were only three questions that had response rates with less than 90% of participants in the sample electing to respond to them. These three questions included the questions on irrigation, dugout refill, and livestock. The lower response rates for these questions can be attributed to producers who did not have that specific feature on their operations. For example, only 3% of producers in the sample indicated that they had irrigated acres. One could therefore, anticipate that for such producers that shelterbelts impact on irrigation efficiency is not a factor they are as informed on or impacted by in terms of management decisions.

In addition, many of the Likert-Scale questions had significant amounts of neutral (or no) responses. For example, for the factor of shelterbelts impact on yields, 46% of respondents indicated a neutral impact. The high amount of neutral responses for this and other questions, could be an indication that respondents are not aware of such changes or did not have any personal experience related to these changes or that when weighing positive verses negative impacts related to that factor the two cancel each other out thus resulting in a neutral response. For example one producer indicated in regards to crop yield that:

> "Shelterbelts compete with the crops for moisture in the summer but they also trap snow so overall their impact is probably neutral on crop yields." (Male, 55 and over).

This example provides some insight into why, in particular for this question, there may have been high neutral responses given.

For the Likert-Scale questions within the questionnaire frequency tables and bar charts were constructed to look at how the survey respondents answered each question. There were different types of questions related to private costs and benefits of field, livestock, and farmyard shelterbelts as well as several questions related to the costs and benefits of ecological goods and services related to shelterbelts in the landscape. For the next several sections the Likert-Scale questions will be grouped in various categories. Several variables overlap between categories and as a result some factors (i.e., changes in microclimate) are included in more than one category. The Likert-Scale ranking questions served as indicators of the relative importance of factors as well as allowed for internal validation of the survey responses.

6.2.3.1 Field Shelterbelt Likert-Scale Questions

There were twelve Likert-Scale questions pertaining to field shelterbelts included in the questionnaire. The twelve factors that were considered characteristic costs and/or benefits (potential economic or non-economic) of field shelterbelts were:

- The establishment and maintenance costs of shelterbelts
- Shelterbelts impact on irrigation efficiency

- Shelterbelts impact on pesticide drift
- The requirement to take land out of production for shelterbelts
- Other agricultural crop prices influence on shelterbelt management
- Shelterbelts impact on soil erosion
- Snow capture by shelterbelts
- Shelterbelts providing wind protection to crops
- Overlapping of seeding and spraying around shelterbelts
- Changes to the microclimate around shelterbelts
- Shelterbelts influence on land values
- Shelterbelts impact on crop yields

The frequency responses for each of these specific factors can be found in Appendix II. For example as seen in figure 11 the factor of shelterbelts impact on crop yield had a mean response of 3.27 which equates to slightly above neutral to the positive side.

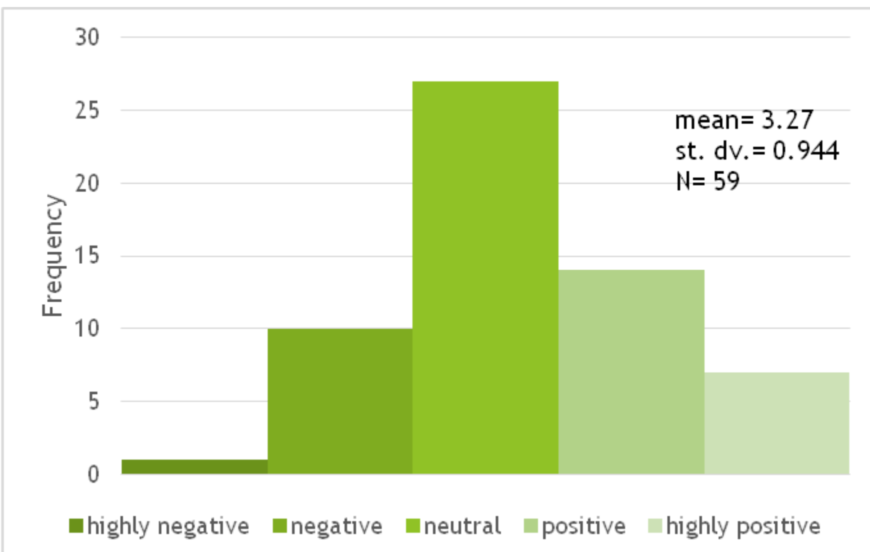

FIGURE 11-DISTRIBUTION OF RESPONSES FOR SHELTERBELTS IMPACT ON CROP YIELDS

Several factors displayed a mean response that was not close to the neutral value and these were identified as either more of a positive or a negative effect. Shelterbelts impact on soil erosion was identified as a positive effect of shelterbelts. This factor had a mean response equal to 4, with 74.1% of respondents indicating a positive or highly positive rating. Figure 12 shows the bar graph of the frequencies of the different responses for the factor of shelterbelts impact on soil erosion.

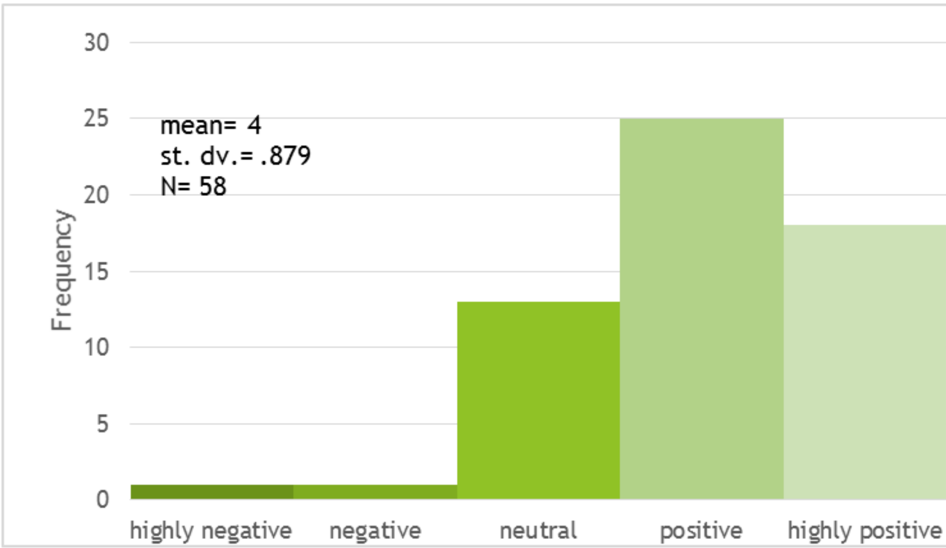

FIGURE 12- DISTRIBUTION OF RESPONSES FOR SHELTERBELTS IMPACT ON SOIL EROSION

These results show producers' level of awareness related to this effect of shelterbelts. Table 2 includes a summary of mean, standard deviation, and number of responses for the remaining factors related to field shelterbelts.

The most negative impact related to field shelterbelts, as indicated by respondents, was overlapping of seeding and spraying operations. Overlapping, or going over the same area more than once, because of shelterbelt presence increases the amount of inputs (i.e., seed, chemical, fuel) required to seed, maintain, and harvest crops. This directly results in additional expenses for producers who have to adjust management to account for the presences of shelterbelts in their operations. Figure 13 highlights that the response for this question were distributed to the negative impact side of the scale which highlights the negative impact that producers see associated with overlapping around shelterbelts. It should be noted that larger, crop production operations were more concerned about overlapping of seeding and spraying operations.

Table 2- Summary of Field Shelterbelt Factors Mean, Standard Deviation, and Number of Response

Factor	Mean	Standard Deviation	N (number of responses)
Shelterbelts impact on crop yields	3.27	0.944	59
The establishment and maintenance costs of shelterbelts	3.10	0.986	58
Shelterbelts impact on irrigation efficiency	2.95	0.613	38
Shelterbelts impact on pesticide drift	3.72	0.840	57
The requirement to take land out of production for shelterbelts	3.12	0.839	58
Other agricultural crop prices influence on shelterbelt management	3.05	0.705	55
Shelterbelts impact on soil erosion	4.00	0.879	58
Snow capture by shelterbelts	3.66	1.027	59
Shelterbelts providing wind protection to crops	3.95	0.804	58
Overlapping of seeding and spraying around shelterbelts	2.60	0.974	55
Changes to the microclimate around shelterbelts	3.81	0.766	57
Shelterbelts influence on land values	3.70	0.925	57

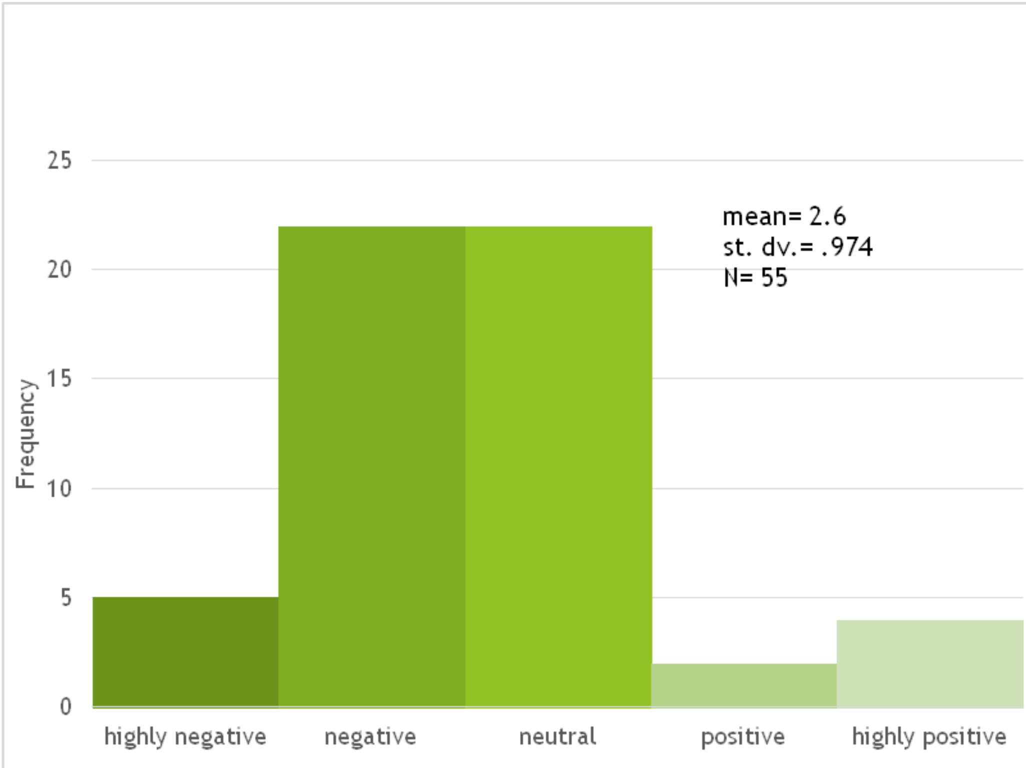

FIGURE 13- DISTRIBUTION OF RESPONSES FOR OVERLAP OF SEEDING AND SPRAYING OPERATIONS

6.2.3.2 Livestock Shelterbelts Likert-Scale Questions

There were seven Likert-Scale questions pertaining to livestock. The Likert-Scale went from highly negative to highly positive for all factors, except cost which was ranked from very high costs to very low costs. The factors related to livestock shelterbelts included in the Likert-Scale question section included: The establishment and maintenance costs of shelterbelt

- Shelterbelts providing protection to livestock
- Shelterbelts impact on feed and water usage by livestock
- Changes to the microclimate around shelterbelts
- Odour mitigation by shelterbelts
- Shelterbelts impact on land values
- Shelterbelts impact on dugout recharge
- Snow capture by shelterbelts

It should be noted that the questions related to livestock protection and livestock feed and water use efficiency had lower response rates. This is largely due to participants who were not involved in livestock production operations skipping these questions. Table 3 summarizes the mean response, standard deviation, and number of respondents for each question. Almost all of the factors, related to livestock shelterbelts had mean responses greater than 3.5 which would correspond to neutral to positive ranking.

TABLE 3-SUMMARY OF LIVESTOCK SHELTERBELT FACTORS BY MEAN, STANDARD DEVIATION, AND NUMBER OF RESPONSES

Factor	Mean	Standard Deviation	N
The establishment and maintenance costs of shelterbelt	3.10	0.986	58
Shelterbelts providing protection to livestock	3.76	0.896	51
Shelterbelts impact on feed and water usage by livestock	3.45	0.832	51
Changes to the microclimate around shelterbelts	3.81	0.776	57
Odour mitigation by shelterbelts	3.4	0.873	55
Shelterbelts impact on land values	3.7	0.925	57
Shelterbelts impact on dugout recharge	3.63	0.787	43
Snow capture by shelterbelts	3.66	1.027	59

Changes to the microclimate from shelterbelts had the highest mean response of 3.81. In addition, a related variable of protection for livestock from shelterbelts had a mean response of 3.73 these two variables, both related to shelter for the livestock, were considered as positive factors influencing adoption of livestock shelterbelts. Figure 14 shows the response frequencies for changes to the microclimate from shelterbelts and Figure 15 shows the responses for protection of livestock from shelterbelts on the Likert-Scale rating[13]. Within the factors related

[13] It should be noted that the most commonly cited cost by livestock producers in the open questions was fencing costs; however, this specific factor was not included in the Likert Scale ranking questions

to livestock shelterbelts, there were no factors with a mean score below 3 (neutral response) indicating that in the overall analysis none of the factors had a pronounced negative impact[14].

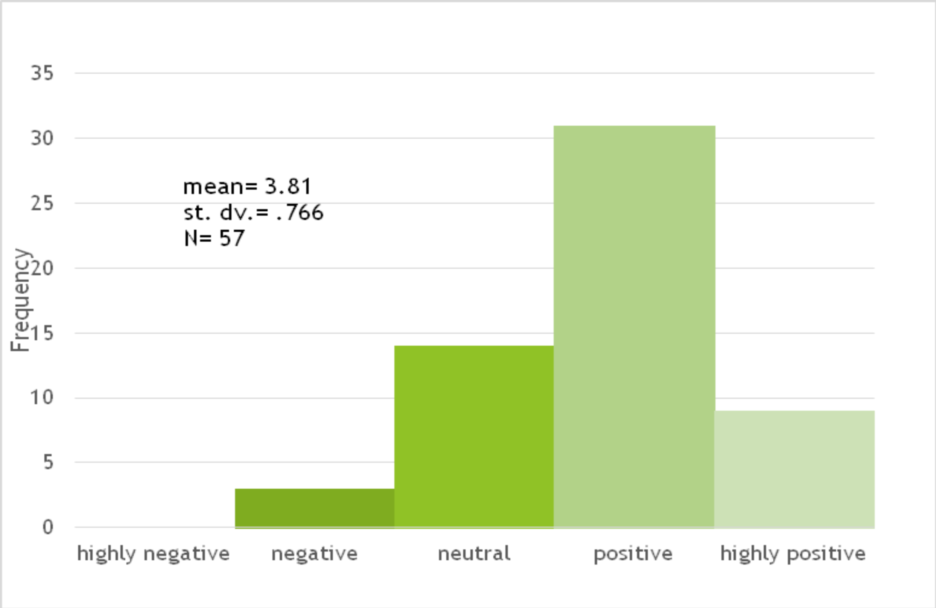

FIGURE 14-DISTRIBUTION OF RESPONSES FOR SHELTERBELTS IMPACT ON MICROCLIMATE

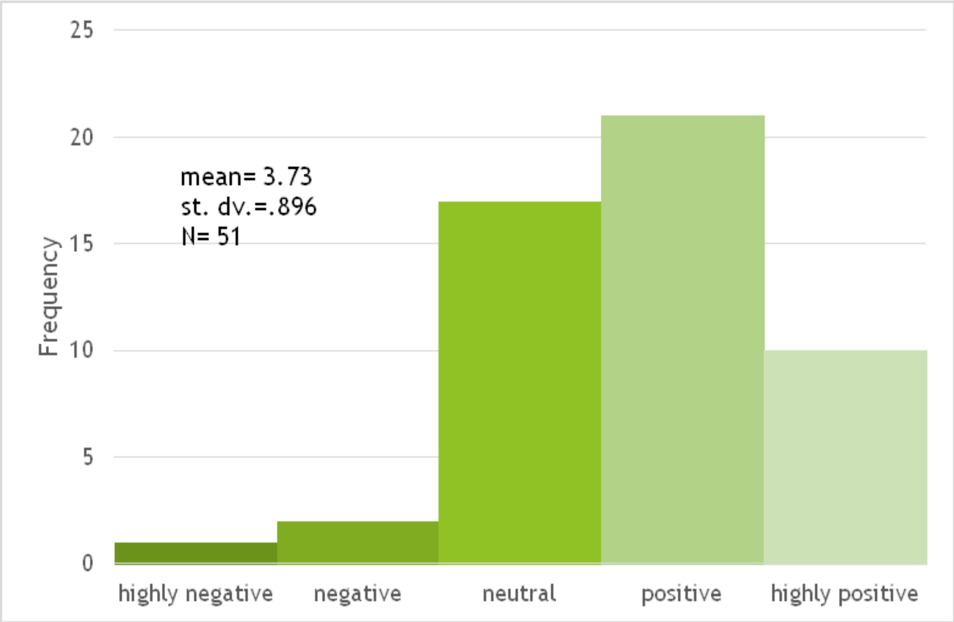

FIGURE 15- DISTRIBUTION OF RESPONSES FOR SHELTERBELTS ABILITY TO PROVIDE PROTECTION FOR LIVESTOCK

[14] It should be noted that snow capture had a standard >1 and that this can have a negative impact on fencing costs for livestock operations. It can also have positive impacts for livestock operations depending on where the snow is being captured and if it protects livestock from snow.

6.2.3.3Farmyard Shelterbelts Likert-Scale Questions

There were eight factors related to farmyard shelterbelts included in the Likert-Scale portion of the survey. The eight factors related to farmyard shelterbelts include:

- Changes to the microclimate around shelterbelts
- Shelter around the home
- Beautification of the farmyard
- Protection of buildings/infrastructure from the elements
- Shelterbelts impact on land values
- Shelterbelts impact on dugout recharge
- The establishment and maintenance costs of shelterbelts

Of the three types of shelterbelts and their related factors, farmyard shelterbelts factors had much higher mean responses with cost being the only factor rated with a mean response less than 3.5 (slightly positive). The frequency bar graph of responses for the establishment and maintenance cost question can be seen in Figure 18 (in the livestock section). Shelter around the home and beautification of the farmyard had the highest mean responses, ranging between positive and highly positive, at 4.66 and 4.56, respectively. The high mean response is a result that in both cases, shelter around home and yard beautification, all respondents indicated neutral or higher on the Likert-Scale. It is interesting to note that these factors rated very highly compared to the factors in livestock or field shelterbelts and indicated the importance of these factors in shelterbelt management decisions. Figure 16 shows bar graphs of the frequency of responses for the factors of shelter around the home and Figure 17 shows the response frequencies for the factor beautification of the farmyard.

The lack of any strong negative factors coming through in the factors related specifically to farmyard shelterbelts indicates that producers are aware of and highly value the benefits associated with farmyard shelterbelts. The costs related to establishment and maintenance was considered the biggest drawback of farmyard shelterbelts. Table 4 includes the mean, standard deviation, and number of responses for each of the factors that are related to farmyard shelterbelts

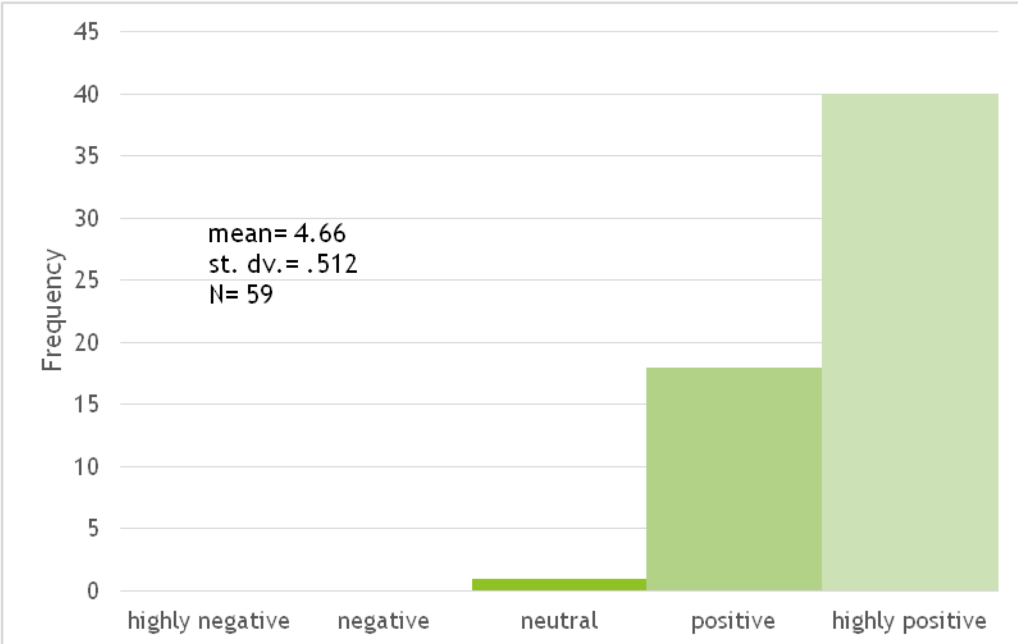

FIGURE 16- DISTRIBUTION OF RESPONSES FOR SHELTERBELTS IMPACT ON SHELTER FOR THE HOME

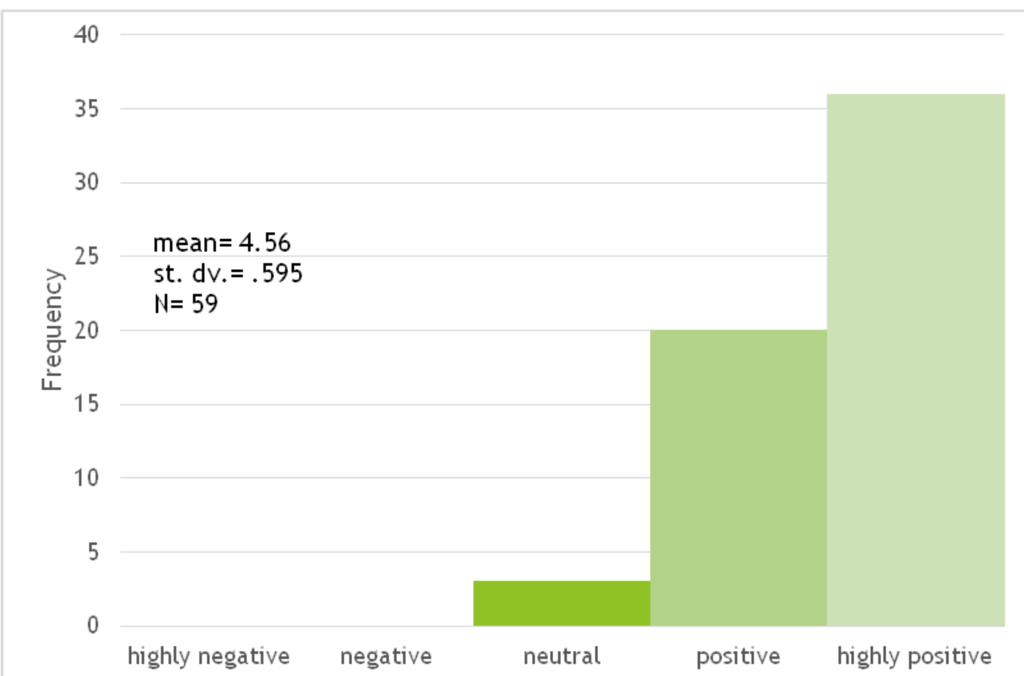

FIGURE 17- DISTRIBUTION OF RESPONSE FOR SHELTERBELTS IMPACT ON YARD BEAUTIFICATION

TABLE 4-SUMMARY OF FARMYARD SHELTERBELT FACTORS BY MEAN, STANDARD DEVIATION, AND NUMBER OF RESPONSE

Factor	Mean	Standard Deviation	N
The establishment and maintenance costs of shelterbelts	3.10	0.986	58
Changes to the microclimate around shelterbelts	3.81	0.766	57
Shelter around the home	4.66	0.512	59
Beautification of the farmyard	4.56	0.595	59
Protection of buildings/infrastructure	4.51	0.569	59
Shelterbelts impact on land values	3.70	0.952	57
Shelterbelts impact on dugout recharge	3.63	0.787	43

6.2.3.4Ecological Goods and Services Related Likert-Scale Questions

The last type of factor questions included in the Likert-scale style of questions was related to provision of ecological goods and services by shelterbelts. There were eight factors that fit into this category as shown below: Changes to the microclimate around shelterbelts

- Improved air quality from shelterbelts
- Protection of water sources through the use of shelterbelts as buffers
- Protection and provision of wildlife habitat in shelterbelts
- Habitat for pollinators in shelterbelts
- Landscape level species biodiversity
- Shelterbelts as a part of sustainable food production systems
- Carbon capture and storage in shelterbelts

All of the factors within this category had mean positive responses above 3.70 (above neutral and close to positive value). Both shelterbelts impact on air quality (Figure 18) and shelterbelts for providing wildlife habitat had mean values above 4.00 (at 4.05 and 4.07, respectively). These values were high despite having some respondents viewing these factors as negative or highly negative[15]. Figure 19 shows the frequencies of responses for shelterbelts impact on air quality and Figure 20 shows the response frequencies for shelterbelts impact on wildlife habitat respectively. It should be noted that although producers generally ranked these questions highly, these types of benefits were not widely identified by producers in the open questions related to costs and benefits. This suggests that while producers do value environmental and ecological benefits, they do not readily recognize them within their decision making process related to shelterbelts. Table 5 provides the mean, standard deviation, and number of responses for the remaining factors related to ecological goods and services.

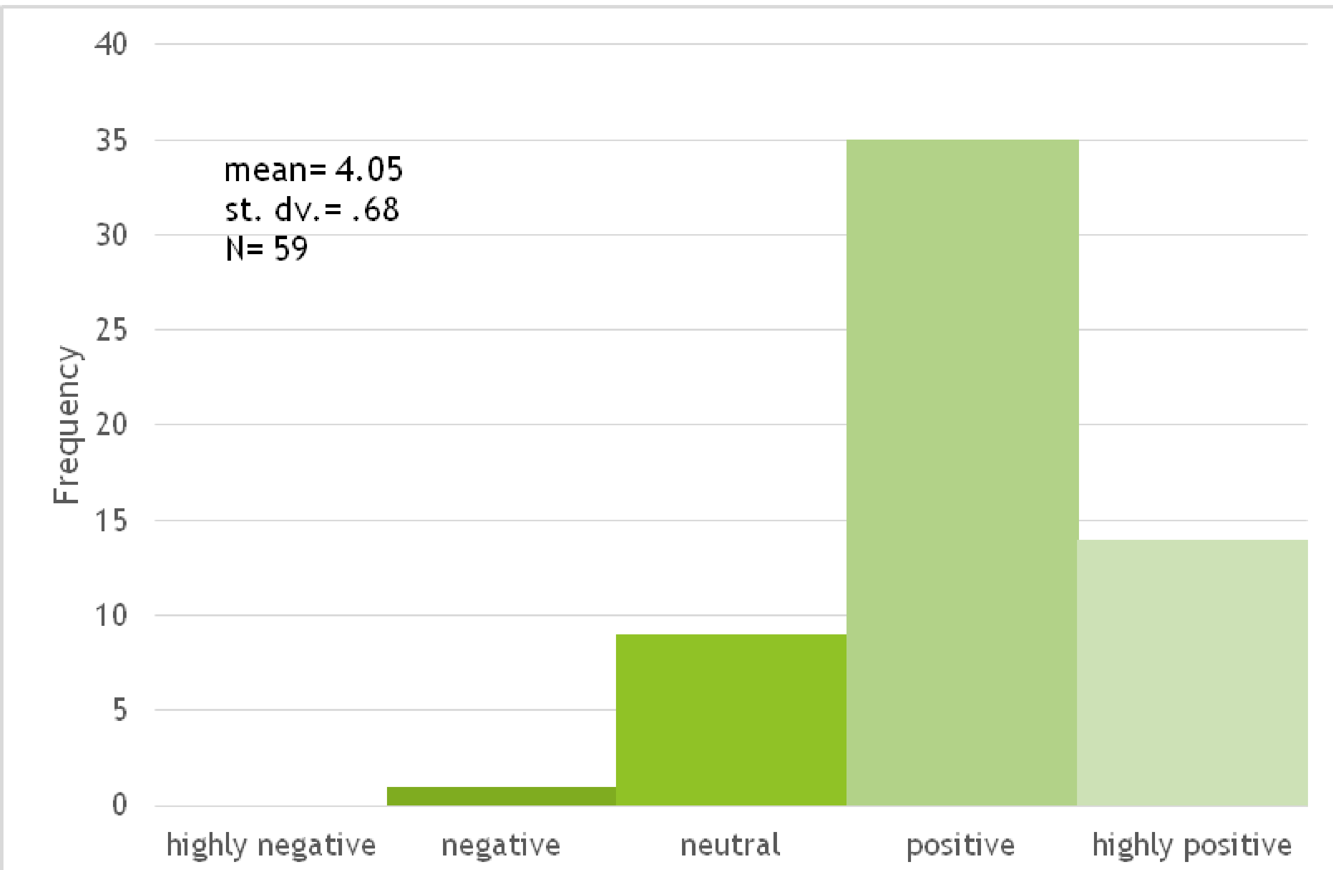

FIGURE 18- DISTRIBUTION OF RESPONSES FOR SHELTERBELTS IMPACT ON AIR QUALITY

[15] In Section 6.2.3.3 several factors (i.e., farmyard beautification and protection for the home provided by shelterbelts) ranked above 4; however, they (unlike the factors in this section) did not have any responses below neutral.

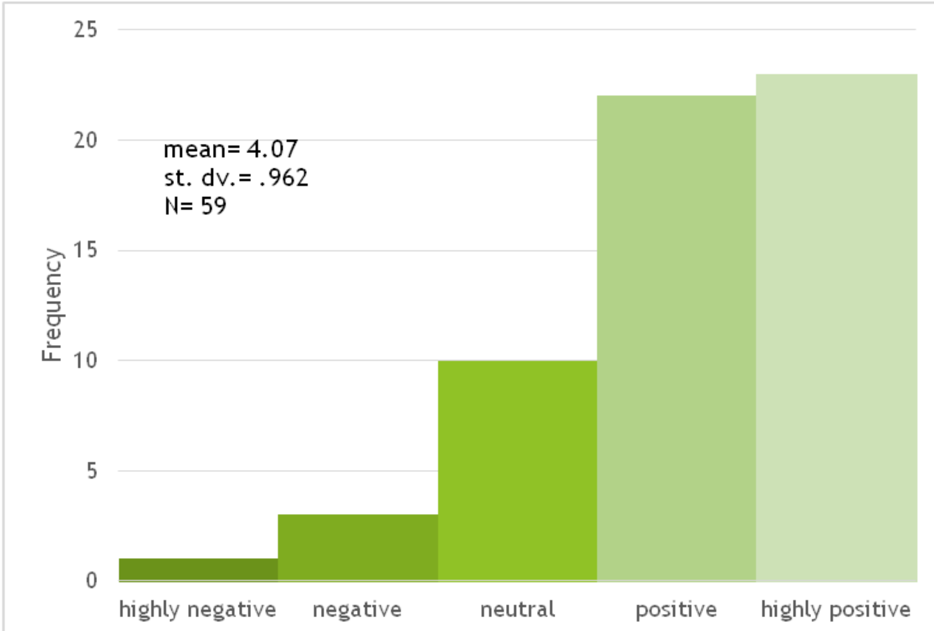

FIGURE 19- RESPONSE DISTRIBUTION FOR SHELTERBELTS PROVIDING WILDLIFE HABITAT

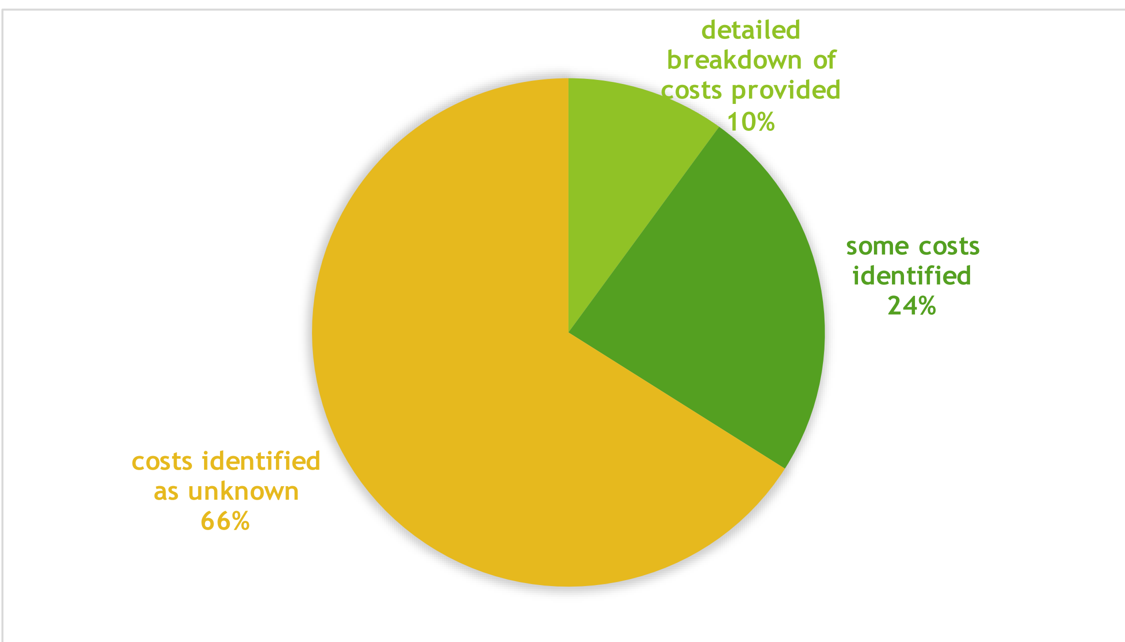

FIGURE 20- SUMMARY OF THE DETAIL THAT RESPONDENTS WERE ABLE TO PROVIDE IN REGARDS TO THE ECONOMIC COSTS OF IMPLEMENTING, MAINTAINING, AND OR REMOVING SHELTERBELTS

TABLE 5-SUMMARY OF GOODS AND SERVICES BY MEAN, STANDARD DEVIATION, AND NUMBER OF RESPONSE

Factor	Mean	Standard Deviation	N
Changes to the microclimate around shelterbelts	3.81	0.766	57
Improved air quality from shelterbelts	4.05	0.680	59
Protection of water sources through the use of shelterbelts as buffers	3.78	0.727	58
Protection and provision of wildlife habitat in shelterbelts	4.07	0.962	59
Habitat for pollinators in shelterbelts	3.92	0.915	59
Landscape level species biodiversity	3.81	0.712	58
Shelterbelts as a part of sustainable food production systems	3.79	0.881	57
Carbon capture and storage in shelterbelts	3.72	0.812	58

6.2.4 Description of Costs and Benefits Identified by Producers

In this portion of the analysis open question responses related to the costs and benefits of shelterbelt planting, maintenance, and removal were identified. Each individual producer's responses were grouped into the category of cost or benefit with each section further being categorized into market or non-market costs or benefits. After this analysis was done, the data of the survey open responses was then grouped into various subcategories, such as those who have removed and those who have not removed shelterbelts, to identify what costs/benefit related factors were most important to these specific groups. The subgroups were selected based on various farm characteristics and farm operator demographic information that was hypothesized to influence management decisions.

Overall, the most commonly discussed/indicated costs were related to the front end investment required to establish shelterbelts in their early years. Similarly, most of the benefits were related to non-market social and environmental benefits later on in the life of a shelterbelt. Agronomic impacts were cited on both the costs and benefit side by many producers. For example: overlapping of seeding and spraying operations, hazard for large equipment, and land out of production were frequently indicated as negative impacts of shelterbelts, while soil erosion control and pesticide drift protection were cited as benefits or positive impacts on production.

The open questions collected information from producers on the direct economic impacts of shelterbelts. Based on the lack of information provided by producers, it is hypothesized that many producers were not well informed on the direct monetary impact associated with shelterbelts. In total, only 34% of producers were able to provide some breakdown of financial costs associated with shelterbelts with only 10% of producers able to provide detail on specific expenditure breakdowns throughout the lifecycle of shelterbelts in their operations. Figure 20 shows the knowledge producers had on economic costs associated with shelterbelts based on the descriptions of the economic costs that producers included in the open questions related to costs associated with shelterbelts.

A lack of knowledge or experience related to the costs associated with shelterbelts, as indicated by 66% of participant's inability to indicate economic costs associated with shelterbelts, will pose a barrier to adoption as well as prevent the spread of shelterbelt adoption through the channels of the income or innovation-diffusion paradigm. This lack of knowledge, particularly associated with economic valuations, indicates that producers who are opting to keep or maintain shelterbelts are making decisions related to shelterbelts more in line with the utility paradigm of adoption. Increasing the understanding and knowledge of the economic impacts of shelterbelts may have the potential to influence adoption decisions under both the income and innovation diffusion paradigms.

In addition the costs and benefits identified by producers, many producers do not actively identify or understand the landscape level impacts of shelterbelts within their operations. For examples, many ecological benefits were not identified by them as costs or benefits to them within their decision making process related to shelterbelts. Soil erosion reduction and wildlife habitat in shelterbelts were the only landscape-level ecological benefits identified by multiple producers as positive impacts (Appendix C). This illustrates that either producers are not aware of the suite of positive/negative impacts or that they do not see them as having an impact on their decision making process. This lack of awareness, acceptance, or acknowledgement related to this particular group of positive benefits could act as a substantial barrier to adoption of future policies aimed at encouraging producers to plant or retain shelterbelts in their operations for the specific purpose of providing ecological goods and services.

6.2.5 Bivariate Correlation Analysis and Mind Maps

A bivariate correlation analysis was conducted with all of the questions in the questionnaire to determine which variables had significant levels of correlation with each other. Statistically significant correlation for the 0.01 level for a two tailed test was used to determine the correlation between factors for demographic data and for the Likert-Scale ranking questions. The demographic data related to the farm operator and the farm itself were analyzed using correlation analysis so that factors that were strongly related could be identified. In addition to the producer's self-identification of costs and benefits associated with shelterbelts, Likert-Scale ranking questions were used to gauge the impact, understanding, and awareness related to specific costs and benefits of shelterbelts, including: agronomic, ecological, and social impacts. The results of the correlation analysis for the Likert Scale questions can be reviewed in Appendix D. This analysis allowed for the production of a mind map using variables that some to strong significant correlation to each other to be connected in a mind map, where lines between variables indicate correlation, to understand the underlying connections in the producers thinking. It further provides important connections for the overall way that producers and landowners connect various factors related to shelterbelt and other landscape level management level decisions.

6.2.5.1 Identification of Strongly Correlated Factors

Correlation analysis was done to indentify the factors that were strongly correlated to other factors identified within the survey. The variables with the highest correlations are indicated in Table 6. The factors that were very highly correlated with each other include farmers age to number of years farming, total farm size to amount of lands rented or leased, and livestock protection and feed use efficiency. All of these factors had strong, positive correlations. No factors were identified with strong, negative correlations.

TABLE 6- VARIABLES WITH HIGH, POSITIVE CORRELATIONS

Variable 1	Variable 2	Pearson Correlation	Significance (using a 2-tail test)	Number of respondents
Age	Years Farming	+0.77	0.000	61
Farm Size	Acres rented or leased	+0.86	0.000	60
Livestock protection from shelterbelts	Shelterbelts impact on livestock feed use efficiency	+0.74	0.000	49

6.2.5.2 Mind Mapping of Correlation

In addition to the initial correlation analysis, which identified variables that were very strongly correlated to each other, the Likert-Scale positive and negative influence ranking questions were also run through the correlation analysis. While correlation variables are not as strong for these types of questions, the correlation matrix was used to give an indication of possible factors that change together. A significant positive correlation for these variables would indicate that as one is ranked highly (towards highly positive) so is the other. This information was used to identify correlated factors as well as to construct a mind map for visualization of the correlations identified within the sample. The mind map can be seen in Figure 21. Appendix D includes Table C.1 which includes the correlations calculated for the Likert-Scale Rankings.

A mind map is a way to visually represent how people think about how things are related or interact using correlation analysis. Using a mind map to show variables with a Pearson Correlation (r value) greater than 0.45, for the various factors included in the Likert-Scale questions, helped to visualize the relationships between variables identified in the bivariate correlation analysis. Figure 21 shows the mind map that was created from the correlation analysis with the factors that have significant correlation (i.e., significantly different from zero at 1% probability using a two tailed test).

The major finding of the correlation mind map exercise was that strictly economic variables were correlated to each other but were not correlated to environmental or social variables; whereas the social and ecological/environmental variables had greater degrees of correlation to each other and with multiple variables being strongly correlated to several others. This is observable in the mind map through the amount of connections each node has and how many times factors or impacts show up on nodes. The economic impacts only show up as correlated to each other and do not connect to the rest of the factors in the mind map. These relationships identified highlight that producers do not observe or recognize direct economic benefits from the ecological and social benefits of shelterbelts.

6.3 Sub-Sample Analysis

It was hypothesized that producers' views on shelterbelts costs and benefits may not be homogenous over the entire province of Saskatchewan. To capture these differences, additional analysis was undertaken. The focus in analyzing these sub-samples is to bring additional insights into adoption, retention, or removal of shelterbelts. In this sub-sample study, two types of sub-samples were identified and looked into with greater detail. These two sub samples are comparing 1) producers who have maintained and kept shelterbelts to those who have removed shelterbelts and 2) producers from different Soil Zones within the province. The results of this sub group analysis are presented in the sub-sections 6.3.1 Shelterbelt Removal and Retention and 6.3.2 Soil Zones

The sub-samples were compared using three comparisons. The first looked at the demographic data of the sub group members. The second compared the responses to the open questions on the costs and benefits (both economic and non-economic) of shelterbelt adoption, retention, and removal. Finally, a comparison of the mean response to the Likert-Scale ranking questions was used to identify factors that were of importance to the sub population that was different than that of the entire population.

6.3.1 Shelterbelt Removal and Retention

The survey asked the participants questions related to their shelterbelt removal activities. Producers were asked if they have removed shelterbelts, why they removed shelterbelts, and

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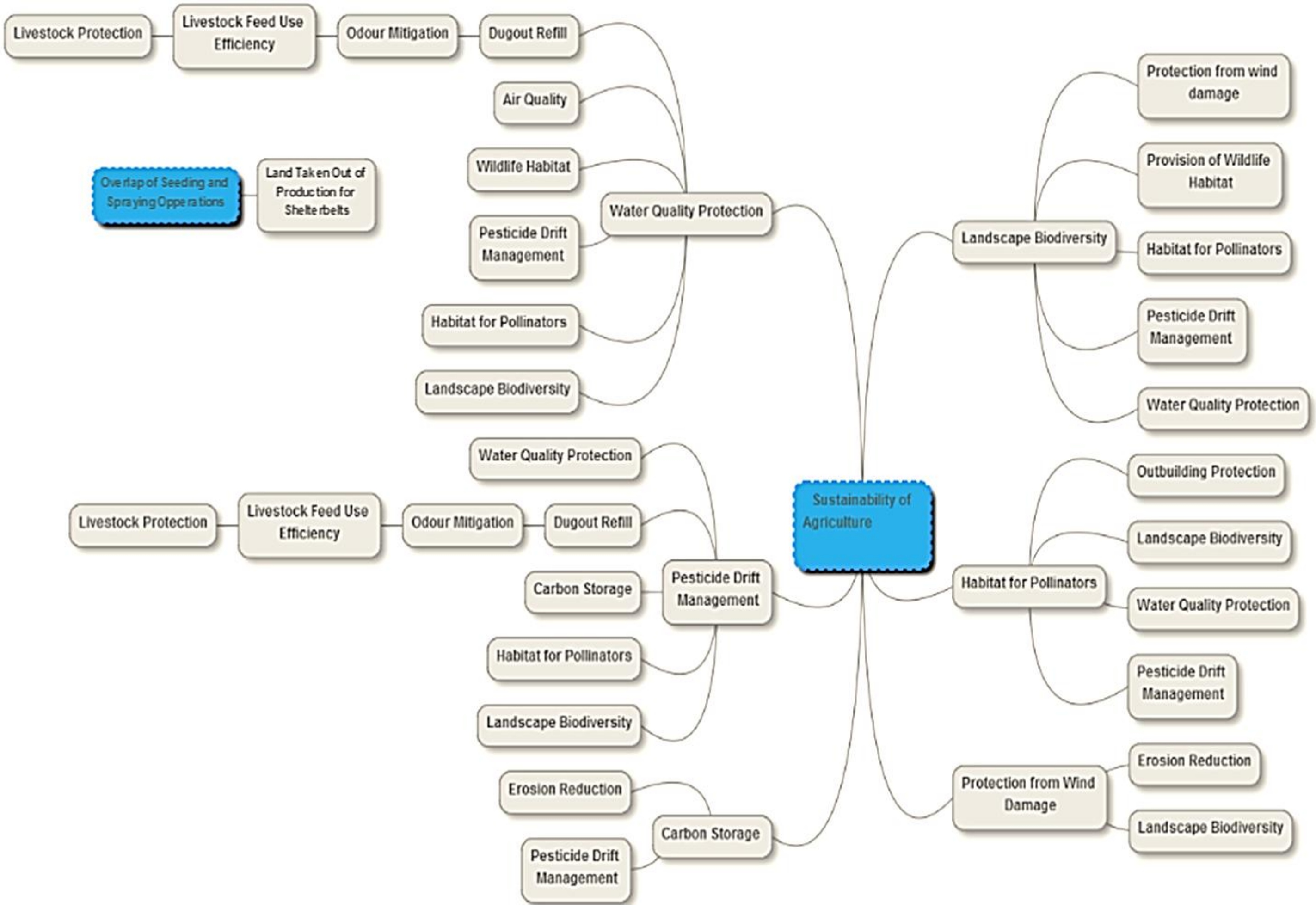

FIGURE 21- MIND MAP OF CORRELATED FACTORS/IMPACTS FROM LIKERT-SCALE RANKINGS

when they removed these shelterbelts. These data were used to identify trends associated with shelterbelt removal on the prairies. This analysis also included identified factors that influenced producers' decision to removal of shelterbelt or their retention. It was hypothesized that those who remove shelterbelts identify more costs associated with shelterbelts than those who do not remove.

In this section an analysis of the open question responses, to the various economic and non-economic factors identified by producers who have removed and who have not removed shelterbelts, are summarized and compared.

6.3.1.1 Demographic Data and Farm Characteristics for Sub-Group

Table 7 shows the characteristics of producers included in the two groups -- those who have removed shelterbelts and those who have not removed shelterbelts. This table includes summary demographic data on the producers and landowners in each sub group as well as descriptive data related to the farm operation and location. This data was used to see if there were differences in the type of producers or farm operations who made up the sub-groups of those who have and who have not removed shelterbelts.

Some of the noteworthy identifying factors from this comparison include those who are removing shelterbelts tend to be slightly older (mean 58 years old) and have more years farming experience (mean 36 years' experience) than those who are not removing(mean 55 years old; mean 28 years' experience). Another noteworthy difference is that the farms where shelterbelts had been removed were larger (average area of the farm of 3375 acres) and tended to be crop production (42% of those who removed n=23) operations. In contrast, those that did not remove shelterbelts tended to be smaller (1771 acres mean) and were mixed operations (36% of operations that have not removed n=37). This comparison of the types of farms and farm operators in each group is important and necessary for designing policy. It may be easier to encourage shelterbelt adoption and retention by younger operators, for smaller scale operations, and for mixed operations than it will be for older operators, for larger scale operations, and crop production operations. With this in mind, policy can be tailored to address the income specific concerns of those removing and to try and encourage further adoption and retention by both groups.

TABLE 7- COMPARISON OF THE CHARACTERISTICS OF PRODUCERS WHO HAVE AND HAVE NOT REMOVED SHELTERBELTS

Characteristic	Shelterbelt Removal (n=23)	No Shelterbelt Removal (n=37)
Age (mean)	58 years	54 years
Years Farming (mean)	36 years	28 years
Farm Size (mean)	3375 acres	1771 acres
Rented Acres (mean)	1198 acres	356 acres
Acres of land rented out (mean)	60 acres	21 acres
Education	Junior high 8% High School 33% Technical diploma 29% University 29%	Junior high 17% High school 39% Technical diploma 19% University 25%
Soil Zone	Brown 8% Dark Brown 25% Black 29% Dark Gray 38%	Brown 8% Dark Brown 11% Black 53% Dark Gray/Gray 28%
Income range	$0-$29,000 33% $30,000- $59,000 13% $60,000-$89,000 4% $90,000-$119,000 4% $120,000-$149,000 0% Above $150,000 38% No response 8%	-$29,000 28% $30,000- $59,000 17% $60,000-$89,000 3% $90,000-$119,000 3% $120,000- $149,000 5% Above $150,000 36% No response 8%
Operation Type	Crop 42% Livestock 8% Mixed 13% Retired/land rented out 29% Other 8%	Crop 31% Livestock 19% Mixed 36% Retired/Land rented out 8% Other 6%

6.3.1.2 Shelterbelt Removal Trends

Several of the open questions in the survey were related to participation in shelterbelt removal activities on their farm. All sample producers were stratified into two groups: (1) Those that participated in removal activities, and (2) those that did not participate in such activities. The sample was divided this way to provide insight into factors that are influencing shelterbelt removal and shelterbelt retention decisions. In total, 39% of producers in the sample indicated that they have participated in shelterbelt removal activities, as compared to 60% indicated that they have not participated in shelterbelt removal activities. The remaining 1% declined to answer these questions.

Of those who had removed shelterbelts, they were asked of their reasons for removal of shelterbelts. More room for maneuvering large equipment and space for equipment was the number one reason indicated for shelterbelt removal. This reason was cited by 42% of respondents who had removed shelterbelts. Age or death of trees was the second most common reason for removal, as cited by 25% of producers who removed trees. Both of these reasons pose potential barriers to future adoption and retention of shelterbelts on the prairies.

Changes in the scale at which production is taking place (i.e., size of farm, size of equipment) coupled with aging of the trees will be a challenge for future adoption and retention. A lack of a free supply to replace these aging trees will reduce the incentives and increase the costs that producers have to replace dead shelterbelts, which will become more of an issue as shelterbelts age. These two factors, as well as factors such as snow capture causing delays for seeding (i.e., slow snow melt) and creating additional fencing costs (i.e., snow capture in fence line increasing repair and maintenance costs), detrimental impacts on soil salinity around shelterbelts, a desire to increase land base, and poor species selection for the region are all reasons that were indicated by producers as reasons for removal decisions. Figure 22 shows the factors that were indicated as being the driving force behind the decisions related to removal of shelterbelts. These factors, indicated as justification for removal, are directly related to the opportunity costs that producers face when making management decisions about shelterbelt adoption, retention, and removal.

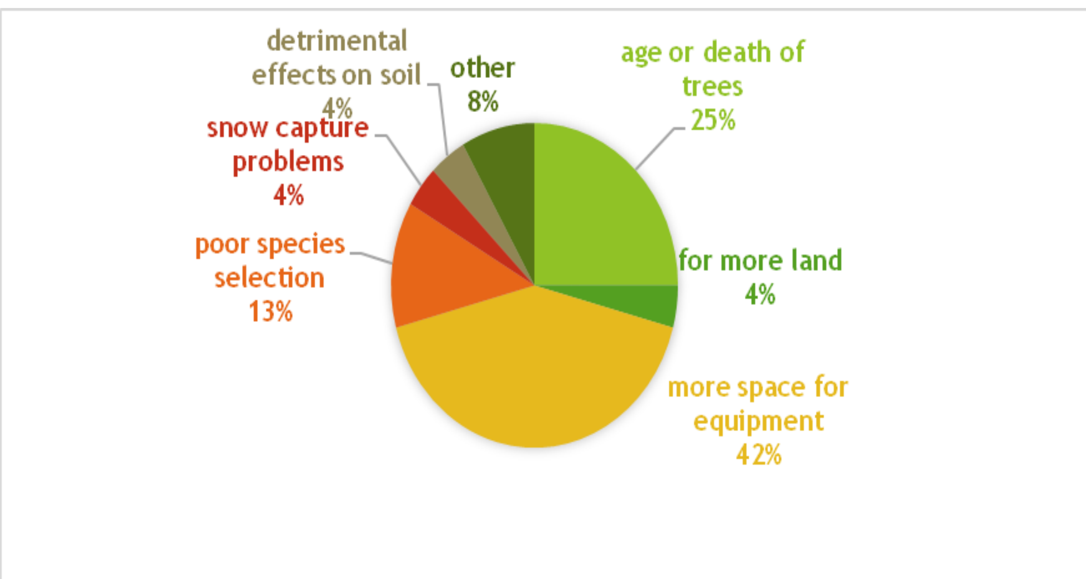

FIGURE 22- REASONS IDENTIFIED BY PRODUCERS AND LAND OWNERS FOR SHELTERBELT REMOVAL IN THEIR OPERATIONS

In addition to the identification of reasons for shelterbelt removal, producers were asked of the year of the removal activity. This data was analyzed using a time series analysis. Figure 23 shows the year of removal and number of producers indicating specific years (during 5-year periods) when removal took place. The correlation (r) value of 0.926 for this relationship shows a strong association between the number of producers removing their shelterbelts (frequency) and year of removal. This indicates that the rate at which producers are removing shelterbelts is increasing.

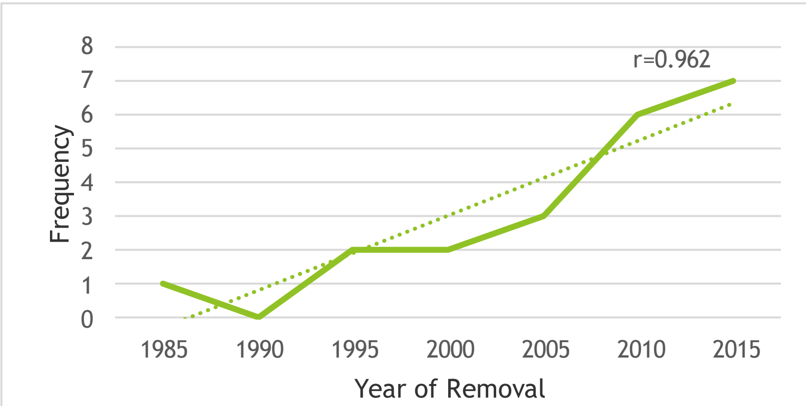

FIGURE 23- TIME SERIES GRAPH OF SHELTERBELT REMOVAL AS INDICATED BY PRODUCERS AND LANDOWNERS WHO HAVE REMOVED SHELTERBELTS

6.3.1.3 Open Question Response Comparison

An analysis of the open question responses to the various economic and non-economic factors identified by producers who have removed and who have not removed shelterbelts are summarized and compared. Appendix C covers the open question comments made by all the producers. The comments have then been further broken down into sub samples for analysis. The sub samples used in this analysis are: 1) responses for those who have removed shelterbelts and those who have not, and 2) responses by soil zone. The breakdown of the costs and benefits identified by the sub groups can be found in Appendix E. These sub groups are the analyzed in this section. Removal and Non-Removal sub groups, shows various costs and benefits (further divided into market and non-market goods) indicated by the two producers in each group. From this comparison it was determined that those who removed shelterbelts identified more costs and less benefits associated with shelterbelts in their operations as compared to those who were opting to retain shelterbelts. This indicates that producers who are making decisions to remove shelterbelts are basing their management decisions on a more narrowly defined understanding of benefits related to the immediate, observable economic gains and costs under best market values (price for forest products and crops).

Producers who are removing shelterbelts indicated a combination of the perceived negative production impacts and lack of positive impacts associated with shelterbelts. This is indicated in both the open question responses related to costs and benefits and in the general comment section about shelterbelts. The following quotes represent some of the themes that emerged from this group related to attitudes about shelterbelts and supporting removal decisions specifically in relation to lost production, costs, or efficiency.

> "I don't like dear and moose eating my crops. They do a lot of damage and having shelterbelts and trees encourages that. I would prefer no trees on my crop land." (Male Producer, age 35-54)

> "We removed a field shelterbelt from [a] line between [our] neighbor's field and ours due to too much snow being trapped there and us not being able to seed until too late in the season." (Female Producer, age 35-54)

The negative impacts and costs that producers identify in relation to shelterbelts in their operations is a major barrier to the retention of current shelterbelts (and the adoption of more shelterbelts in the future) and will continue to influence the removal of shelterbelts in the prairies.

Conversely, the group of producers who indicated shelterbelt retention (or not having removed shelterbelts) can be considered to have a more robust understanding of the positive and negative impacts of shelterbelts in their production systems. Producers maintaining shelterbelts are considering a much greater range of benefits (social and environmental) and are including a more holistic integration of benefits related to shelterbelts in their operations. Some of the comments that producers in this group include:

> "I really enjoy the habitat in and around shelterbelts and the chance to get to see wildlife, birds, and a change in the landscape from just crops." (Male producer, Age 35-54)

> "[Shelterbelts] provide huge environmental protection in the farmyard and field. [We] have seen crop increases of yields of 30+%, for organic production….. We have used wood from the natural bush and planted trees to make lumber for some of the buildings [on our farm] and we also sell firewood which [in] some years is

> up to 60% of our farm sales. I like that trees slow down water flows and reduce some of the issues that happen when there are no trees [i.e., water erosion]. We also collect 6 varieties of wild mushrooms in the bush as well as in the understory of the forest belt." (Male producer, over 55 years of age)

This more diverse and large scale understanding is likely contributing to this group's decisions related to shelterbelt retention and continued or future adoption. In addition, these types of comments suggest that the group of producers who are not removing shelterbelts are making management decisions that most closely resemble the utility paradigm, as many of the benefits they identified for themselves were not strictly economic but also included feelings of enjoyment and non-extractive use. In addition, some of these producers have diversified their operations in order to get economic benefit from their shelterbelts. This is highlighted by the organic producer who sells lumber and firewood from both planted shelterbelts and natural forests on his land. This producer highlighted what several producers in this group indicated and highlight that this group of producer's behavior fall into the income and utility paradigms.

6.3.1.4 Likert Scale Question Comparison

The Likert Scale questions were grouped using Split File analysis in SPSS and the mean response for each factor was calculated for the sub-groups of those who have and have not removed shelterbelts[16]. The mean response for each sub-group was then compared to the mean. Table 8 shows the mean responses of the entire sample and the means of those who have and have not removed shelterbelts in order to identify factors from the Likert Scale Ranking questions that are of importance to each sub-group.

Overall, the means for the sub-groups were similar to each other and to the sample mean as well. The factors reflecting degree of influence of neighbours and habitat for pollinators means varied by greater than 0.5 of a response. Factors that varied by 0.5 or greater of a response were examined as if the factors are equal to or greater than 0.5 the average mean for the two groups would fall in a different response category.

[16] The Likert Scale Factors are ranked from Highly negative 1 to highly positive5 , except for the factor of For the Likert Scale Factor of how much influence neighbours have on management decisions the Likert Scale was ranked using the terms very strong (1), strong (2), some (3), minimal(4), and none (5) for degree of influence

TABLE 8- MEAN RESPONSE OF THE SUB GROUPS (THOSE WHO HAVE REMOVED AND HAVE NOT REMOVED SHELTERBELTS) AND THE ENTIRE SAMPLE FOR THE LIKERT SCALE RANKING QUESTIONS

Factor	Entire Sample Mean (n=61[17])	Shelterbelt Removal Mean (n=23)	No Shelterbelt Removal Mean (n=37)	Difference between two groups mean response
Neighbours Influence[13]	3.64	3.25	3.86	-0.61
Impact on Yields	3.27	3.13	3.37	-0.24
Impact on Irrigation Efficiency	2.95	2.93	2.96	-0.03
Impact on Pesticide Drift	3.72	3.91	3.61	0.3
Requirement to take Land out of Production	3.12	3.09	3.09	0
Crop Price Influence	3.05	2.91	3.09	0.18
Impact on Erosion	4.00	3.82	4.09	-0.27
Snow Capture	3.66	3.48	3.80	-0.32
Wind Damage	3.95	3.86	3.97	-0.11
Changes to the Microclimate	3.81	3.91	3.76	0.15
Overlapping of Seeding and Spraying Operations	2.60	2.77	2.41	0.36
Dugout Refill	3.63	3.80	3.50	0.3
Livestock Shelter	3.73	3.76	3.73	0.03
Livestock Feed Use Efficiency	3.45	3.53	3.42	0.11
Odour Control	3.4	3.61	3.32	0.29
Shelter for the Home	4.66	4.61	4.69	-0.08
Shelter for farm infrastructure	4.51	4.65	4.43	0.22
Beauty	4.56	4.70	4.49	0.21
Air Quality	4.05	4.22	3.97	0.25
Water Quality Protection	3.78	3.90	3.71	0.19
Wildlife Habitat	4.07	4.04	4.11	-0.07
Habitat for Pollinators	3.92	4.26	3.71	0.55
Biodiversity Provision	3.81	3.78	3.85	0.07
Agricultural Sustainability	3.79	3.9	3.74	0.16
Greenhouse Gas Mitigation	3.72	3.83	3.68	0.15
Land Values	3.7	3.65	3.85	-0.2

Figures 24 and 25 illustrate the response for the question on the degree of influence neighbours[18] have on management decisions for those who have and who have not removed shelterbelts. Both groups mean response fell between some and minimal with producers who have not removed shelterbelts having a mean response closer to "minimal" in regards to the degree of influence neighbours have on their management decisions. The mean response of those who have removed shelterbelts fell closer to the category of "some" influence. In addition,

[17] One participant did not indicate removal or non-removal activity. This participant was included in the mean for the entire sample but was not included in the means for the sub-samples

there were more respondents in this group who indicated strong and very strong degrees of influence of neighbours. This illustrates that those producers who are removing shelterbelts indicate more influence of neighbours on their management decisions. This in combination with the removal group tending to be larger operations, supports the theoretical framework of the innovation diffusion paradigm that proposes that larger operations are more likely to adopt changes first and that their behavior is diffused to the majority through influence. Those that indicate higher degrees of influence are more likely to be influenced by their neighbour's management decisions.

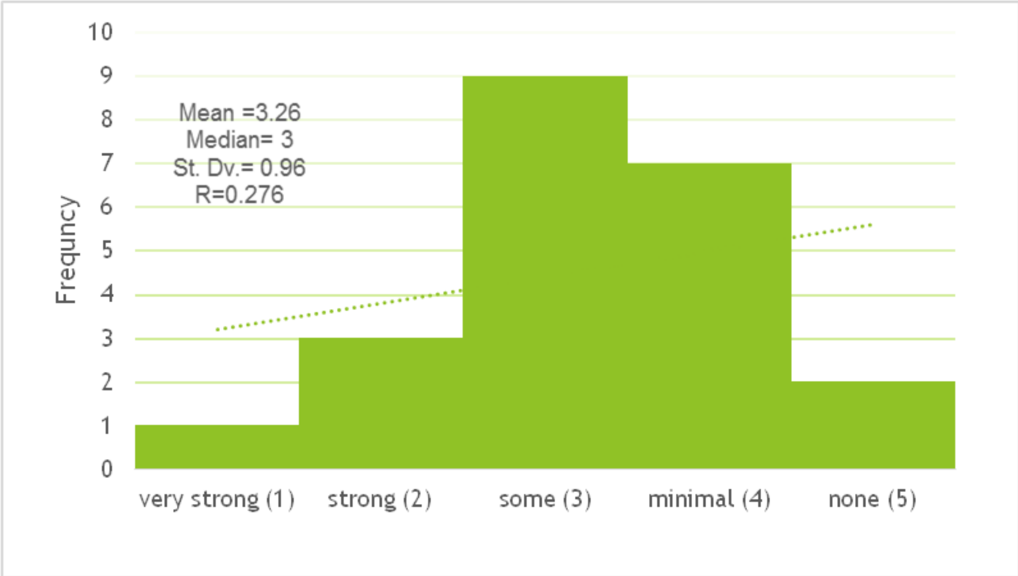

FIGURE 24-DEGREE OF NEIGHBOURS INFLUENCE ON MANAGEMENT DECISIONS AS INDICATED BY PRODUCERS AND LAND OWNERS WHO HAVE REMOVED SHELTERBELTS

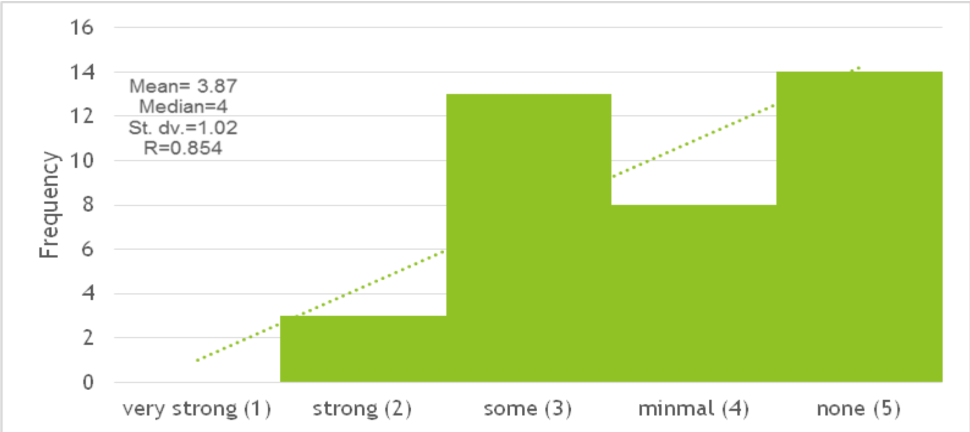

FIGURE 25- DEGREE OF INFLUENCE OF NEIGHBOURS ON MANAGEMENT DECISIONS AS INDICATED BY PRODUCERS AND LANDOWNERS WHO HAVE NOT REMOVED SHELTERBELTS

In addition to the factor of neighbours influence, the factor of the impact of shelterbelts providing shelter for pollinators was also ranked by more than 0.5 of a response between the two groups. Interestingly, the group who has removed shelterbelts indicated habitat for pollinators in shelterbelts more highly with a mean response of 4.26 while those who have not removed shelterbelts indicated had a mean response of 3.76. This means that those who have removed shelterbelts have a mean response between positive and highly positive whereas those who have not removed shelterbelts mean response is between neutral and positive. It is noteworthy, that the group of producers who have removed shelterbelts ranked several of the other ecological factors higher than those who have not removed shelterbelts. These include the factors related to shelterbelts impact on agriculture sustainability, greenhouse gas mitigation, and water and air quality; however, this group did not identify these same factors as benefits to themselves or their operations even though they indicted that these factors were positive benefits overall in the Likert-Scale rankings.

The above results indicate that this group of producers, those removing shelterbelts, is making management decisions related to shelterbelts in a way that supports that income paradigm. Currently, this group identifies more tangible costs and even though they rate some ecological factors highly they do not see any direct economic benefit to their operations. This is highlighted by the open response questions where producers were asked to identify the costs and benefits to them of shelterbelts. The group who has removed shelterbelts indicated more costs than benefits and less environmental/ecological benefits for themselves. As a result, this group has made management decisions to remove shelterbelts based on their assessment of the costs and benefits they receive from shelterbelts. In addition, the higher degree of influence of neighbours indicated by this group suggests that the shelterbelt removal trend may be an example of where a new management practice (removal) is being tried and observed by some producers with others waiting and observing to see the results.

6.3.2 Soil Zones

Geology, climate, soils, and ecozones interact to shape the landscape of a region. These factors interact with each other and give rise to the physical geography that is seen by humans living on earth. In Saskatchewan, these factors vary greatly across the province. Data collected in the surveys was grouped based on Soil Zone, as Soil Zones are shaped by the geology and climate of the region. In addition, agricultural conditions and practices vary between the Soil Zones (Strategic Policy Branch, Marketing and Policy Directorate, 2000). Soil Zones represent the long term climatic and vegetation patterns of regions (Davey and Furtan, 2008) and as a result, are important indicators and drivers for management decisions, particularly within agricultural landscapes.

In Saskatchewan, there are five Soil Zones where agriculture production occurs. They are the Brown, Dark Brown, Black, Dark Gray, and Gray Soil Zone (Padbury, 2006). Figure 26 shows the Soil Zones of Saskatchewan. In the study survey, legal land description of each producer was collected. This information was used to determine the Soil Zone for the location of the farm. Appendix E. Table E.2 includes the producer's responses to interviews/open questions related to the costs and benefits of shelterbelts for each Soil Zone. For the purpose of this analysis, producers of the Gray and Dark Gray Soil Zones are grouped together as there was only one producer from the Gray Soil Zone. Table 9 shows a summary of the descriptive and demographic data for the producers and landowners who participated in the survey from each Soil Zone. The information from this table is referenced and discussed in Sections 6.3.2.1 to 6.3.2.4 inclusive.

6.3.2.1 Brown Soil Zone

The Brown Soil Zone, shown in Figure 26, is the southernmost Soil Zone in the province and covers the majority of the southwest corner of the province. This region of the province is in the area known as the Palliser triangle. This region was deemed by an early explorer, John Palliser, as unfit for agricultural production or settlement (Lemmen and Dale-Burnett, 1999). The agricultural production of this region is limited by low precipitation, low soil organic matter, and warmer mean annual temperatures; therefore, production mostly consists of small grain production and large grassland areas for livestock (Strategic Policy Branch, Marketing and Policy Directorate, 2000)

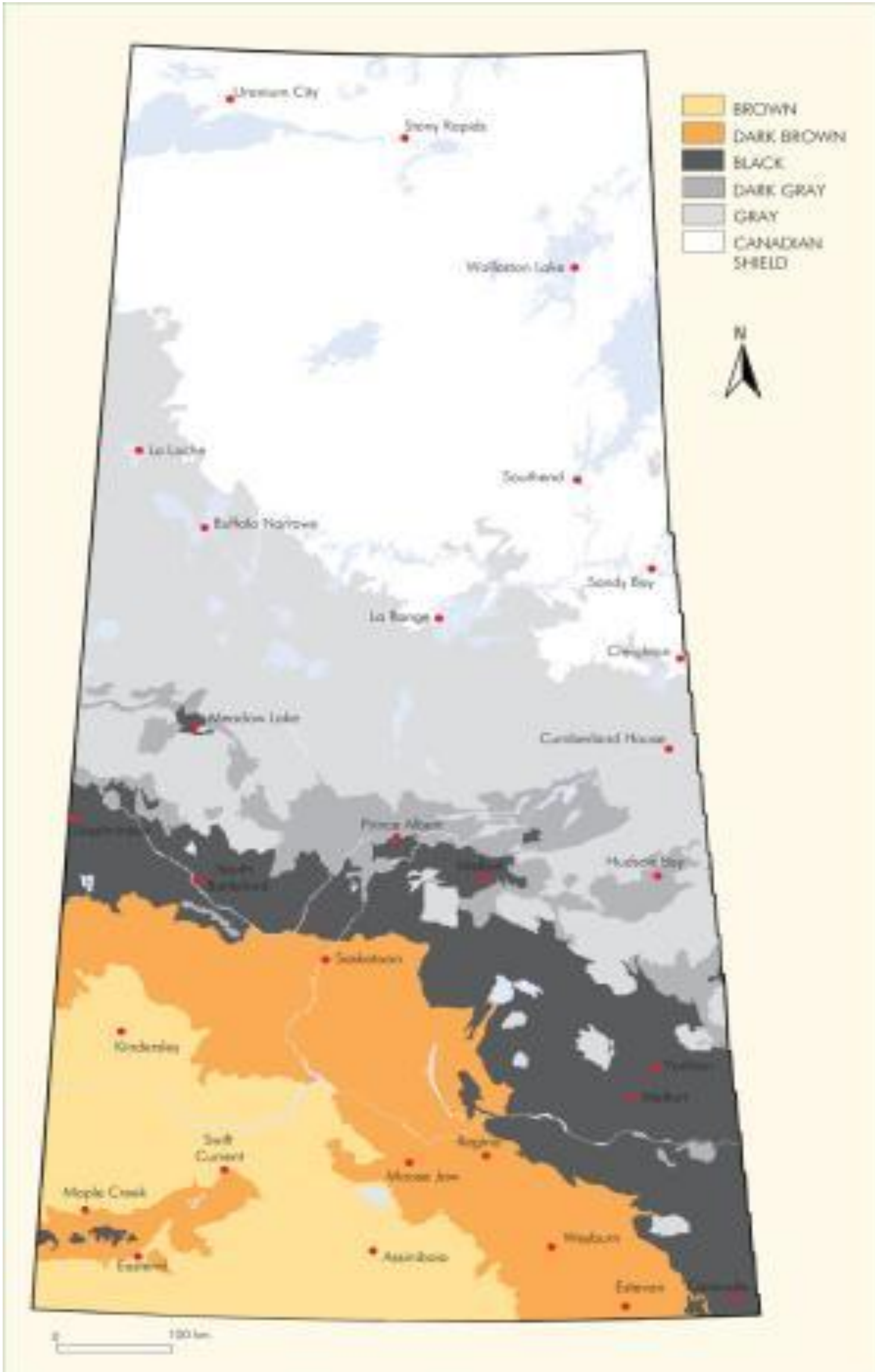

FIGURE 26- SOIL ZONES OF SASKATCHEWAN (PADBURY, 2006).

TABLE 9- SUMMARY OF DEMOGRAPHIC AND DESCRIPTIVE DATA FOR SURVEY PARTICIPANTS FROM EACH SOIL ZONE

Characteristic	Brown Soil Zone	Dark Brown Soil Zone	Black Soil Zone	Dark Gray and Gray Soil Zone
Age (mean)	55 years	59.4 years	52.4 years	56.9 years
Years Farming (mean)	37.4 years	34 years	25.1 years	34.6 years
Farm Size (mean)	6552 acres	4087 acres	1539 acres	1580 acres
Rented Acres (mean)	1472 acres	884 acres	536 acres	557 acres
Acres of land rented out (mean)	0 acres	31 acres	32 acres	55 acres
Education	Junior High 40% High School 40% Technical Diploma 0% University 20%	Junior High - 10% High School- 50% Technical Diploma- 20% University- 20%	Junior High -7% High School- 26% Technical Diploma- 33% University -34%	Junior High -11% High School- 47% Technical School- 16% University- 26%
Income range	$60,000-$89,000- **17%** Above $150,000 -**83%**	$0-$29,000- **20%** $30,000- $59,000 -**10%** $60,000-$89,000- **10%** Above $150,000-**40%** No response- **20%**	$0-$29,000- **28%** $30,000- $59,000- **20%** $90,000-$119,000- **4%** $120,000-$149,000-**7%** Above $150,000- **30%** No response -**11%**	$0-$29,000- **42%** $30,000- $59,000- **16%** $90,000-$119,000-**5%** $120,000-$149,000- **5%** Above $150,000 **32%**
Operation Type	Crop - 83% Mixed -17%	Crop- 60% Mixed- 10% Retired or land rented out – 20% Other -10%	Crop -30% Livestock- 22% Mixed- 30% Retired or land rented out - 10% Other -8%	Crop- 21% Livestock- 16% Mixed- 32% Retired or land rented out – 26% Other- 5%

The sample of producers from the Brown Soil Zone had the fewest number of producers in it with 8% of the sample. This sub-sample had the largest mean farm size at 6552 acres. This is consistent with the fact that the Brown Soil Zone in Saskatchewan has a low population density with Swift Current and Kindersley as the largest urban centers and a relatively low, spread out rural population (Padbury, 2006), which is associated with large farm size (Strategic Policy Branch, Marketing and Policy Directorate, 2000).

The producers in the sample included large farms[19] (80% of producers had greater than 4000 acres), high income (80% of operations reported annual gross sales of over $150,000), and higher frequency of crop production operations (as shown by 80% crop farms vs. 20% mixed farms). It is interesting to note that the producers in the Brown Soil Zone had the highest proportion of respondents with only junior high school education (40% of respondents indicated that they did not continue with schooling as they had plans from a young age to take over the family farm). Junior and high school educated producers comprised 80% of this sub-sample with only 20% of producers in this sample having more than high school education. The producers tended to be older (60% over 55 years of age) with many years of farming experience (80% having more than 25 years of farming experience). There were no organic producers in this region.

In this sample, 60% of producers had not removed shelterbelts from their land and 80% had considered planting more in the future. In fact, in this region, the highest proportion (80% of total) of producers indicated that they plan to plant more shelterbelts in the future. This could be due to the climactic zone that their operations are located in, as the region is devoid of native trees. All of the producers in the Brown Soil Zone are in the mixed grassland ecoregion. This ecoregion, which is a part of the area known as the Palliser triangle, is classified as semi-arid with low levels of annual precipitation (250-350 mm annually) with the majority of moisture coming as snow (University of Saskatchewan, 2008). About 80% of the producers in this region cited snow management, particularly for added moisture in fields, as an important benefit related to shelterbelts. This suggests that producers in this region value shelterbelts highly for moisture management.

The major reason cited by producers in this region who had removed shelterbelts (40% of producers surveyed) was to make more room for larger equipment either in their yards or fields, or improve maneuverability of equipment within fields by increasing the distance between shelterbelts rows. All of the producers who had removed shelterbelts indicated that they planned to plant more shelterbelts in the future. Changes in farming practices, technology, and

[19] The same criteria from Section 5.3.2.2 Farm Size was used to classify farm size in this section. "The mean farm size (in acres) at the time of the 2011 agricultural census was 1,668 acres (Statistics Canada, 2012e). This mean was used to divide the data into three sub categories for farm size: 1) small operations -- less than or equal to 640 acres, 2) mid-sized operations between 640 acres to 1960 acres, and 3) large operations those greater than 1960 acres" (see Section 5.3.2.2)

equipment sizes have altered how producers think about and use shelterbelts but it appears that in the drier Brown Soil Zone the benefits of using shelterbelts are well recognized by the producers surveyed and that their management decisions weigh the pros/cons (costs/benefits) on a field/case basis to determine how and where they should use shelterbelts in their operations.

The open question responses to the costs and benefits related to shelterbelts shows that producers in this Soil Zone as a group see more benefits (22 total) coming from shelterbelts than costs (14 total). Concerns about the PFRA closure and future tree stock for replanting/new planting were often highlighted by this group as a concern. Many mentioned that they liked having the option of the tree supply available should they decide to plant more trees. Some of the comments this group made about shelterbelts include:

> "We appreciate the shelter the trees provide as we live in a flat and windy part of the province." (Male, 35-54 years of age)
>
> "I think shelterbelts are a huge protection from the elements [i.e., wind, storms, snow]. The concerns I have is the shutting down of the Indian Head facility. I think it was [a] very important part of the prairies." (Male, over 55 years of age)
>
> "We have got all of our trees from Indian Head. I think it should stay open but don't know who would run it....We had problems this spring with snow piling up. I think it's partly related to a lot of neighbours taking out there shelterbelts and the snow getting trapped on our land….This area has been known for its dry years…so usually the snow capture is very important. (Male, over 55 years of age)
>
> "[The benefits [of shelterbelts] include snow trap, wind reduction, and beauty…[Shelterbelts] do add extra time in fields if you have to go around them." (Male, over 55 years of age).

The comments in the open questions are internally validated by the Likert-Scale ranking question responses where producers in the Brown Soil Zone unanimously indicated overlap around shelterbelts as a negative or highly negative factor, and conversely snow capture for added moisture was unanimously selected as positive or highly positive factor. The mean response for this group for overlap of seeding and spraying was 1.75 which corresponds to the highly negative to negative range. The mean for the entire sample for this factor was 2.6 (negative to neutral). Compared to the other Soil Zones, the Brown soils mean ranking of the factor of seeding and spraying overlap was the lowest and indicates the significant impact that this cost has in this region where there are larger-scale crop production operations. In addition, snow capture was rated in the positive to highly positive range (mean response 4.25) for the Brown Soil Zone as compared to the entire sample mean of neutral to positive (3.66). The Brown Soil Zone was the only Soil Zone to have a mean response for this question above positive and this speaks to the moisture limiting nature of production in this region.

In addition to these factors, 5 factors of the 8 ecological factors in the Likert-scale rankings were rated above 4 as compared to only 2 for the whole sample mean. This indicates that producers in this region highly value the ecological and environmental provisions of the trees and shelterbelts in the region. The relative scarcity of natural treed environments could play a role in this high regard of trees and their benefits to the landscape as well as the harsh moisture limited climate of the region.

In summary, shelterbelts remain important in the drier regions of the province for moisture management, and snow management; however, based on producer comments the more desirable locations for shelterbelts in this region may be shifting from rows within fields to rows around perimeters of fields and within farmyards. Changes in agricultural technologies and management have reduced the demand for shelterbelts located in frequent rows within fields to less frequent rows and perimeter marking belts. This region is more aware of moisture needs/requirements of their crops as well as about conserving available field moisture. Costs related to future tree supplies for the vast amounts of land owned by each individual producer, as well as the upfront labour demand for planting/maintenance in a low population area, may serve as significant barriers to further implementation of shelterbelts as an agricultural management tool in this region.

6.3.2.2 Dark Brown Soil Zone

The Dark Brown Soil Zone encompasses the most intensively farmed region in the province of Saskatchewan (Strategic Policy Branch, Marketing and Policy Directorate, 2000). It lies in the mid-south west corner of the province between the Brown and Black soil (as shown in Figure 26). In this region, there is still low annual precipitation and soil organic matter; however, both of them are higher in this region than in the Brown Soil Zone. This is because of a trend of increased soil organic matter and precipitation along a gradient from the southwest corner to the northeast corner of the provinces agricultural soils (Strategic Policy Branch, Marketing and Policy Directorate, 2000).

Some 16% of the producers were located in this Soil Zone. This is more than in the Brown Soil Zone and less than in the Black and Dark Gray Soil Zones. Mean farm size of farms in this Soil Zone was 4087 acres. This is consistent with the fact that farms in the Dark Brown Soil Zone tend to be more frequent and smaller than in the Brown Soil Zone and less frequent and larger than in Black/dark Gray Soil Zone (Strategic Policy Branch, Marketing and Policy Directorate, 2000).

Of the total number of producers in this Soil Zone, 60% indicated that they had a crop production operation, 10% indicated mixed operation, 20% were retired/renting out the land, and 10% had other specialty operations. There were no pure livestock operations in the sample from the Brown Soil Zone. The majority of the farms in the sub-sample (60%) were large and the rest (40%) were classified as small-scale operations[20]. There were no mid-sized farms in the sub-sample of the Dark Brown Soil Zone. The income levels of farms in this region included 30% of producers having gross incomes less than $59,999, 50% making more than $60,000, and 20% not reporting/indicating farm income. The income level seems to be more modest than in the Brown Soil Zone.

In the Dark Brown Soil Zone 60% of producers indicated that they have removed shelterbelts and 60% also indicated that they have no plans to plant more shelterbelts. Producers seemed to be split when asked if the benefits of shelterbelts are greater than the costs: 50% of producers indicated yes while the other 50% indicated no/uncertain. This is similar to the responses to the open questions, where the producers were asked to describe the costs and benefits that they receive from their shelterbelts, as the producers for this Soil Zone came up with an equal amount of costs and benefits as a group.

Producers from the Dark Brown Soil Zone, as a group, came up with an equal amount of costs (25) and benefits (25) from shelterbelts on their land. The majority of the costs indicated were market related (18) with negative impacts on crops or increased labour requirements as being the most commonly indicated cost. The majority of the benefits indicated by this sub group of producers were non-market (17) with the majority related to benefits received directly

[20] Refer to footnote 15 and/or section 5.3.2.2 Farm Size for details on these categories.

from farmyard specific shelterbelts (i.e., shelter for the home, protection for farm infrastructure, beauty around my home, etc.). This indicates that for producers in the Dark Brown Soil Zone, farmyard shelterbelts are highly valued or important; however, when it comes to shelterbelts in the field recognizing the benefits to justify the costs is more difficult[21].

The producer's responses to the open questions are supported by their responses in the Likert-Scale section. Almost 44 % of producers in the Dark Brown Soil Zone indicated production related costs, such as land out of production, as a negative or highly negative cost of shelterbelts in their operations. When it came to benefits, factors related to farmyard shelterbelts received the highest positive rankings. About 89% of producers in this Soil Zone indicated that protection and shelter around their home and yard was a positive or highly positive benefit associated with shelterbelts. In this region, producers ranked habitat for pollinators in shelterbelts highly. The mean response was 4.22 which corresponds to the positive to highly positive range. The mean response for the entire sample for this factor was 3.92, which corresponds to neutral to positive. The factor of improving the quality of habitat and amount of pollinators in the region may be a potential way to encourage additional shelterbelts and shelterbelt retention within this Soil Zone. Several producers in this region spoke about concerns of shelterbelts attracting wildlife that results in significant damage to crops and yields. This negative impact of wildlife population on crops is reflected in this Soil Zone having the lowest mean response related to the factor of shelterbelts providing wildlife habitat within landscapes. The mean response for this factor for this group was 3.78 as compared to 4.07 for the entire sample. Wildlife populations and their impact on crop production is viewed as less of a positive impact in the Dark Brown Soil Zone. This could impact the receptiveness of this producer group to policy aimed at biodiversity specifically for wildlife.

Overall, the observations collected from the Dark Brown Soil Zone sub-group are noteworthy for future policy aimed at increasing tree plantings in the prairies. Farmyard shelterbelts are important in this region and the benefits are well understood and observable. The benefits related to field shelterbelts are not easily observable or perceived by individual land owners. As a result, the costs seem to greatly outweigh the benefits at the farm level. Perhaps,

[21] Appendix E includes a table with all of the costs and benefits indicated by producers in the Brown Soil Zone.

there is an opportunity to increase the education and awareness of landscape and long term benefits related to shelterbelts for this producer group.

6.3.2.3 Black Soil Zone

The Black Soil Zone lies north and east of the Dark Brown Soil Zone (shown in Figure 26). In this Soil Zone, the mean annual temperatures are lower with a shorter growing season than the southern Soil Zones of the province. The mean annual precipitation is higher in this region. These factors combined allow for a wider variety of cropping operations and practices (Strategic Policy Branch, Marketing and Policy Directorate, 2000). The farm size in this region tended to be smaller than Brown/Dark Brown Soil Zone counterparts and larger than Gray/Dark Gray operations (Smith, 2013). This diversity of cropping practices and farm size is reflected in the sample data.

Of the total sample of producers, 44% were located in the Black Soil Zone. Mean farm size was 1539 acres which is smaller than the 2517 found by a study by Smith (2013). The characteristics of amount of farms and farm size are consistent with the trend that farms in the Black Soil Zone are smaller and occur more often with the landscape than in the Brown or Dark Brown Soil Zones.

There was a diverse group of producers represented with 30% crop production enterprises, 22% livestock operations, 30% indicated mixed operations, 3% acreage owners, and 15% had their land rented out. In the Black Soil Zone sample, 44% of operations were small[22] farms, 37% were medium sized farms, and 19% were large operations. This is consistent with the trends observed for this region from the Statistics Canada 2011 census. The income levels for the farms in this region were as follows: 54% of respondents in the region indicated incomes of less than $59,999 (with 33% of these having incomes below $29,999), 13% indicated income between $60,000 and $149,999, and 33% indicated incomes above $150,000. About 11% of producers in the region chose not to answer this question. The Black Soil Zone displayed a high degree of diversity in incomes which is a reflection of the diversity of operations and farm sizes in this region.

[22] Refer to footnote 15 and/or Section 5.3.2.2 Farm Size for details on these categories.

In the Black Soil Zone, 27% of producers indicated that they have removed shelterbelts while the remaining 73% indicated that they have not removed shelterbelts from their operations. The producers who had removed shelterbelts indicated a broad range of reasons for their decisions. For example, 29% of producers indicated that large equipment for seeding and spraying was the main reason for removal, along with reasons related to age of trees/tree death, a desire for additional crop land, snow capture delaying seeding, poor species selection, and overlapping of seeding and spraying operations all of which were at 14.2%. This broad range of reasons for removal indicates the diversity in operations in the Black Soil Zone as well as additional challenges faced by farming in a moist northern region. About 75% of producers in the Black Soil Zone indicated that they have been or are considering planting more shelterbelts in the future. Some producers indicated that they will use natural reforestation or transplanting of tree species to reduce costs now that the shelterbelt center is no longer providing trees free of charge.

It is noteworthy that only 50% of producers in the Black Soil Zone indicated that they plan to use shelterbelts in the future and only 46% of producers felt that there was adequate information available to them about shelterbelts. Producers in this region zone are geographically farther away from the shelterbelt center and may not have had as much direct access or opportunity to utilize their services. Several producers in this region made comments related to the fact that some shelterbelt species, particularly caragana, that are important in more southern regions are not suited to agriculture in the more moist northern regions, where native trees and forested land exist. One producer near the Carrot River indicated:

> "Caragana are like weeds and they get back into the natural bush which causes other problems. They are all along the Carrot River now [and competing with native species]." (Male producer, over 55 years of age).

Challenges associated with species selection, natural forested lands, lack of extension activities, and inadequate information about shelterbelts (specifically related to the regional context) were identified as potential barriers to adoption in this region.

Producers in the Black Soil Zone indicated more market and non-market benefits than costs associated with shelterbelts and trees within their operations. In total, producers in this region indicated 13 market related benefits and 21 non-market benefits compared to 16 market costs and 7 non-market costs or impacts. In addition to identifying more categories of benefits than costs, this group also indicated more consumptive uses of their shelterbelts, including berry picking, hunting, and harvesting wood for lumber and firewood. In addition to consumptive uses of shelterbelts, non-consumptive uses of shelterbelts, such as beauty and bird watching, were also identified. By recognizing and engaging in multiple uses of their shelterbelts and natural forested areas, this group presents a more holistic anthropocentric approach to valuation beyond the income generated through agricultural activities. Diversifying their use of the shelterbelts to include consumptive and recreational uses of shelterbelts may be part of the reason for the low removal rate among this group. In total, 73% of producers in this region indicated that they have not removed shelterbelts, whereas in the combined sample, 60% or less indicated that they had not removed shelterbelts.

Reponses in the Likert-Scale ranking section of the survey for this group revealed that the factor of water quality protection was important, with a mean response of 4. This places this factor in the positive category as compared to the sample mean of 3.78 which is in the neutral to positive category. In addition to this factor, the factor of land taken out of production for shelterbelts had a mean response of 3.27 (neutral to positive) which was higher than the sample mean of 3.12 and higher than both the Brown (mean 2.775) and Dark Brown (mean 2.63) Soil Zone (where the mean responses both fell into the category of negative to neutral). The remaining factors were ranked with comparable means to both the sample and to the other Soil Zones. Producers in this region may be more receptive to policies aimed at taking land out of production as compared to other Soil Zones. This may be due to the fact that some regions in this Soil Zone are more marginal for agricultural production and that land use change to trees or shelterbelts results in less of an economic trade-off.

Overall, the group of producers in the Black Soil Zone displayed a high amount of diversity both in operation type, size, operators, and valuations of benefit flows from shelterbelts. This group identified more benefits, or positive impacts, associated with shelterbelts than they did for costs. The group seems to be influenced by the guiding principles of the utility paradigm and income paradigm. Furthermore, more than 70% of producers in this region have not engaged in shelterbelt removal.

6.3.2.4 Dark Gray and Gray Soil Zone

The Dark Gray and Gray Soil Zones of Saskatchewan are the northern most agricultural soils in the province (Padbury, 2006). These Soil Zones are in the boreal transition ecoregion and are the northern most agricultural soils in the province at the boundary between moist mixed grasslands and boreal forests (Champagne et al. 2012). Figure 26 shows the geographical location of the Gray and Dark Gray Soil Zones. The Gray Soil Zone is characterized by favorable moisture conditions but a shortened growing season compared to other agricultural Soil Zone regions in the prairies (Strategic Policy Branch, Marketing and Policy Directorate, 2000). These are the conditions in which producers in this region make agricultural management decisions.

In the sample, 31% of respondents were located in the Dark Gray or Gray Soil Zones. The mean farm size in this region was lower than the Brown and Dark Brown Soil Zones and comparable to that found in the Black Soil Zone. The mean farm size in this region was 1580 acres. Here 53% of the operations were small scale, 26 % were large, and 21% were medium operations. This is consistent with the expectations for this region as the sample contained a mix of operation types and the Gray Soil Zones tend to consist of smaller scale operations and frequent farm steads (Padbury, 2006). In this sub-sample, mixed operations were the most common operation type at 32% of all operations, followed by crop operations at 21%. Livestock operations and retired farmers each comprised 16% of the farms in this sub-sample. Land was rented out by 11% of producers, while acreage owners comprised 5% of total number of producers in the region. The variety in farm size and type indicates the broad spectrum of operations in the sub-sample.

About 42% of the producers in these Soil Zones indicated gross farm incomes of less than $29,000 and only 21% of producers indicated gross farm income level between $30,000 and $119,000. This is reflective of the higher proportion of small-scale farms in the area. The lower income of farms in this reason is related to farm size and the additional challenges faced by producers in more Northern agricultural regions (such as a shorter growing season). The large amount of producers in the lower income categories could act as a barrier towards further adoption and maintenance of shelterbelts.

Producers in the Dark Gray and Gray Soil Zones were almost evenly split on those who have and have not removed shelterbelts. About 47% of producers in the region indicated shelterbelt removal compared to 53% who indicated no removal. More space for equipment and age of trees/tree death were the most commonly indicated reasons for removal, with each representing 33% of all reasons cited. About 22% of producers indicated poor species selection, while 11% indicated other reasons for not removing shelterbelts from their farms.

About 73% of producers in this region indicated they have considered or are considering planting more shelterbelts on their operations. This is the second highest proportion of producers indicating plans to plant more (Brown Soil Zone being the highest). Also, 68% of producers in this region indicated plans to continue actively using shelterbelts in their agricultural operations. This was the highest proportion of any Soil Zone indicating plans for continued use of shelterbelts. This perhaps is a result of 73% of producers indicating that the benefits associated with shelterbelts were greater than the costs, while only 27% of producers indicating benefits not being greater than costs (or they were uncertain).

In addition to the above results, the majority of producers in this region in response to open question identified more benefits than costs associated with shelterbelts. Collectively this group indicated 19 costs and 38 benefits (the most of any Soil Zone). Similar to producers in the Black Soil Zone, this group of producers indicated a more diverse and broad list of benefits, including benefits related to consumptive and recreational uses of shelterbelts. This was the only group to include the benefit of carbon sequestration as a benefit associated with shelterbelts. Similarly they were also the group to indicate the most benefits related to environmental and ecological impacts of shelterbelts.

Analysis of the Likert-Scale questions revealed that many of the environmental and ecological factors were ranked highly by producers in the Dark Gray and Gray Soil Zones. In this region, five of the eight factors associated with ecological or environmental impacts were ranked about 4 (positive to highly positive range). The other three ecological factors were ranked at 3.79 to 3.94, which fall in the neutral to positive range. This group collectively ranked ecological and environmental factors as important. Their responses were higher than that for the sample as a whole. The entire sample ranked only 2 of the ecological factors out of 8 above the level of 4. This higher ranking of environmental and ecological impacts is similar to that found in the Brown Soil Zone. Part of the reason for these higher rankings related to the environmental impacts of shelterbelts could be that agriculture in these more extreme (moisture limiting or growing season limiting) areas of the province provides additional challenges that require producers to be more informed and sensitive to the limitations of their production environments.

Overall, producers in the Gray and Dark Gray Soil Zones seem to be more aware of the breadth of benefits associated with shelterbelts within their operations, particularly related to the landscape level and ecological significance of shelterbelts. Producers in this region were diverse and overall income levels in this region were lower, with 42% having incomes less than $29,000. The diversity in operations is indicative of the variety of farms that are adopted in the region. The lower income level of many producers in this region may act as a barrier in the future to additional adoption and retention of trees; however, natural regeneration and transplanting of native species in this region may act as a cost reducing measure for producers.

6.3.2.5 Summary

The agricultural Soil Zones of the prairies are united by the agricultural production that takes place on them; however, the challenges and factors that impact decisions related to shelterbelt are not identical. Producers in the more extreme regions where moisture or growing season length are particularly limiting (Brown and Gray Soil Zones) are more in tune with the environmental and ecological significance of shelterbelts. Producers who have more favorable moisture regimes, soil organic matter, and growing season (Dark Brown and Black Soil Zones) are more focused on production related aspects of shelterbelt.

In all Soil Zones, producers were aware of some of the tradeoffs between agricultural production efficiency and shelterbelts benefits in their operations. However, producers in the Dark Brown Soil Zone noted this aspect in particular. Overall, when producers were left to identify costs and benefits associated with shelterbelts, in all the Soil Zones, implementation, maintenance, and production efficiencies were the greatest costs and protection for farmyards and infrastructure were the most important benefits. In the open questions, ecological, environmental, and social benefits were not as commonly cited as important aspects associated with shelterbelts. These findings suggest an area where future extension and educational campaigns could play a significant role in increasing awareness and influencing producers' management decisions.

6.4 Summary

The survey was analyzed using a mixture of statistical and comparative methods. Overall, producers were aware that tradeoffs exist when using shelterbelts in production but could not put specific financial value or quantifications to these tradeoffs. Costs of implementation, maintenance, removal, and production challenges related to shelterbelts were recognized, but could not be monetized. Many producers indicated that costs associated with shelterbelts were absorbed as a part of the cost of farming. On the benefit side, benefits related to farmyard shelterbelts were ranked very high, whereas ecological and social benefits were not often highlighted as major benefits. The nature of the costs associated with shelterbelts and the lack of benefit recognition together pose a significant barrier to future shelterbelt adoption and retention.

Shelterbelts are an important part of agricultural landscapes for a variety of reasons but their adoption and retention hinges on management decisions made by individual producers. About 39% of producers in the sample indicated they have removed shelterbelts and only 56% of producers indicated that they plan to continue to use shelterbelts in the future. Both of these proportions are indicative of current trends and attitudes towards using less shelterbelts in agricultural production. This could be a concern in the context of climate change and risk abatement in production. Decreasing biodiversity is a major concern going forward if the trend towards accelerated removal continues.

Producers in different Soil Zones of the province identified varying degrees of understanding and recognition of costs and benefits of shelterbelts. Producers in more extreme production regions tended to have a broader understanding of the impacts, both positive and negative, associated with shelterbelts in their production operations. Producers in the Dark Brown Soil Zone identified more costs than benefits associated with shelterbelts. Regional policy consideration for the different operation types and climactic conditions under which producers make management decisions will be crucial for policy aimed at increasing awareness, education, retention, and implementation of shelterbelts in all Soil Zones.

7. Study Results

In this section a summary of potential barriers to the adoption and retention of shelterbelts, areas of future research, and potential future policy recommendations are covered. These sections were created using a combination of insights from the literature review and the data collected and analyzed from the surveys. These sections are important in summarizing future challenges associated with shelterbelt adoption and retention on the prairies particularly in regards to climate and land use changes.

7.1 Barriers to Adoption and Retention of Shelterbelts

In addition to identifying the adoption paradigms that each producer group (those removing and those not removing) fit into, it is important to understand the characteristics of the producers that make up each group. This information aids in the development of more effective policy measures. Time series analysis indicates that the rate that shelterbelts are being removed has increased in the last 30 years. Changes in scale and technology related to production as well as age or death of trees are the most common reasons indicated by producers for shelterbelt removal on the prairies. The increase of removal activities in recent years poses a concern from the environmental perspective. The trend towards removal is indicative of a trend that may act as a serious barrier to adoption of shelterbelts in Saskatchewan.

There are many potential barriers to the adoption and retention of shelterbelts that can be identified from the results of this study. In this section some of the barriers that were identified from this research will be reviewed. Some of the barriers to adoption were identified based on the farm and farm operator demographics. One of the first potential barriers that was identified was the age of the producers, particularly those over the age of 55 years. This may pose a barrier to adoption and maintenance of current shelterbelts, as farmers closer to retirement may have less incentive for the long-term management of the farm, and in particular, in terms of needed investment for shelterbelts.

In addition, land tenure may be another potential barrier in the retention and further adoption of shelterbelts. A significant amount of production occurs on land that is leased or rented. Producers who are renting land may have less of an incentive to manage long-term soil fertility and production. This could have an adverse impact on the way they manage the land in terms of shelterbelts as those who do not own the land have less of an incentive to manage it with long term sustainability in mind. Furthermore, management decisions on the rented/leased lands may be influenced by the land owners (i.e., enforcing shelterbelt retention or showing no interest in maintenance of shelterbelts). Those renting out land tended to be older operators with smaller holdings, which suggests the high likelihood for future sale to larger operations. Under these circumstances there is even a higher probability that shelterbelts may be removed, as shown by the results of this study.

In addition to land tenure and age impacting shelterbelt retention/adoption or removal, the analysis found that farm size and type were also strong influences on management decisions and could act as potential barriers to further adoption and retention of shelterbelts. In the sample, large holding crop operations were the most likely to remove shelterbelts. The 2011 Statistics Canada data indicated that the trend is towards fewer, larger farm operations in Saskatchewan. This trend coupled with the results of this sample indicates that amount of shelterbelts in Saskatchewan could be on trend towards a reduction in shelterbelts. Overcoming the negative impacts and providing positive benefits will be essential for this group to overcome this potential barrier to adoption.

In addition, a major barrier to the future adoption and retention of shelterbelts is changes in the scale of production and production technologies within prairie agriculture. The scale at which producers are farming and the large size of equipment that is being used in production today is vastly different from that of the past. These changes have resulted in challenges for producers for maneuvering around existing shelterbelts and often act as a discouragement for future or additional plantings. In addition to the nuisance of having to go around shelterbelts, overlapping of seeding and spraying operations around shelterbelts is inefficient and creates additional expenses for producers. These production related tradeoffs of maintaining shelterbelts act as a barrier to future retention and plantings of shelterbelts.

The heavy front end investment of labour related activities, tree seedlings, and the long length of time before benefits are seen from the shelterbelts are also major barriers to the future adoption of shelterbelts, particularly for non-farmyard shelterbelts. In addition to the labour and time required for initial planting and maintenance of new trees, labour supply is often difficult to come by in rural areas and the planting and maintenance activities often conflict with farm operation related activities. The burden of costs associated with the provision of shelterbelts in agricultural systems often outweighs the benefits for many years until the trees are established.

Producers seem to be more aware of some of the costs, tradeoffs, and opportunity costs associated with shelterbelts than they are about the benefits of shelterbelts, particularly landscape and ecological benefits. Even though producers indicated a variety of cost associated with shelterbelts, they were often unable to provide details on the breakdown of these costs or put actual dollar figures on them. This lack of awareness about actual monetary costs and little knowledge of benefits indicate that producers are unaware of the full suite of costs and benefits. In addition, many of the benefits associated with shelterbelts are not captured entirely by the private land owners and therefore do not factor directly into the decision making process related to shelterbelts.

7.2 Areas of Future Research

More research is required in identifying the short and long term trade-offs of shelterbelts to determine the point at which benefits from shelterbelt outweigh costs. This may be accomplished through, further education/extension activities in order for farmers to make the best educated decisions towards adoption and maintenance of shelterbelts. The development of an economic model that is capable of illustrating the costs and benefits associated with planting, maintaining, and removing shelterbelts under different farm specific management regimes and characteristics (i.e., Soil Zone, size) would be ideal to aid producers in making decisions that are tailored to their needs to maximize benefits and minimize costs. An assessment of the impact of recent policy changes (i.e., loss of free tree program) could be an important aspect of this model. The current context without a subsidy policy substantially increases the costs borne by producers associated with shelterbelt implantation and renovation.

Further research is also needed to quantify the total economic value of shelterbelts to society, the ecosystem, and the private producers. The data analysis showed that producers view economic and environmental related variables or factors as separate entities. This is an interesting finding and one that requires additional research and policy considerations. As a part of this evaluation, specific information on greenhouse gas storage/balance in the tree biomass and soil, as well as the impact of land use change impacts would be particularly useful for climate change modeling and scenarios. These types of information would be very important for the future development of models for use by scholars, policy makers, and producers.

In addition to the economic and policy related areas of research, scientific research could focus on some of the impacts of shelterbelts on agronomic factors, such as yield, feed efficiency for livestock, snow capture, disease resistance, weed seed interception, soil stabilization, and competition zones under new technology and production practices (such as zero till and chemical fallow). Much of the research on these topics predates current production practices and was conducted under conventional agricultural production systems (i.e. tillage, summer fallowing). Updating the body of research surrounding the impact of shelterbelts on crop production, as well as livestock production, will be important moving forward to better encourage adoption and retention of shelterbelt stocks. Finally, further research into the wide spread removal of shelterbelts and the channels of influence for these types of decisions could aid in more practical policy targeted at encouraging less removal and possibly further adoption.

7.3 Policy Implications and Recommendations

Overall, producers face many challenges to implementing shelterbelts. Chiefly, the costs associated with shelterbelt are borne almost entirely by the private land owner. At the same time, the benefits are not entirely private. These two factors combined together create a situation where shelterbelts will be undersupplied if left to the free market. Thus a case can be made for a policy to be created and aimed at reducing the barriers to adoption and retention of shelterbelts in the prairies for the benefit of society. If shelterbelts are to remain a part of the prairie landscape, as well as be a part of future greenhouse gas mitigation strategies, policy aimed at reducing the costs and internalizing the benefits associated with shelterbelts in agriculture landscapes is essential. Recognizing the long-term benefits of shelterbelts in the agricultural landscapes will be imperative to both effective policy and long term management planning and risk mitigation. The optimal shelterbelt design, including species, density, orientation etc., will vary for different production schemes, soil zones, and farm size.

As climate change concerns continue to come more into focus, it becomes more important to ensure that agricultural producers are equipped with the information and management strategies to overcome the many and increasing challenges they face. Policy aimed at internalizing external benefits for the provision of ecological goods and services and reducing the costs associated with providing these services may bring forth higher rates of adoption or retention of shelterbelts. Effective policies for this purpose may include several types of options. One option is to penalize those who are creating negative externalities through their operations. This type of policy option may be difficult to implement and/or enforce due to the large scale of agricultural operations and difficulty associated with monitoring impacts. Although options such as remote sensing could be used to monitor shelterbelts and tree removal, at this time no such program of monitoring has been implemented specifically for shelterbelts in the prairies. Other options may include economic incentives, such as tax deductions, markets for carbon credits, or the reduction of costs associated with providing ecological best management practices. Providing producers with incentives to manage lands under environmentally sound management practices will require policy intervention; as many of the short run costs associated with shelterbelts are difficult for producers to overcome when the majority of benefits of shelterbelts are long term and landscape level.

From the analysis, it was concluded that those who are removing shelterbelts make decisions related to shelterbelts differently than those who are not removing shelterbelts. This was identified as these two groups consider different mixes of market and non-market costs and benefits in their decision making. This difference in the way that these two groups (those removing and not removing shelterbelts) of producers view shelterbelt costs and benefits makes policy aimed at shelterbelt management more complex and may indicate a need for a more targeted localized approach to incentives as highlighted by the different views of producers from the various soil zones. Considering factors that relate both to income, utility, and social influence (innovation diffusion paradigm) when developing policy will be important to improve retention rates and encourage future adoption. Measures to reduce or slow down removal activities should also be considered in policy initiatives related to shelterbelts and tree plantings in agricultural landscapes on the prairies. This is something that policy directed at encouraging shelterbelt adoption and retention could reward through incentives and credits for their contributions to the long term sustainability of agriculture.

Age of trees, tree death, and proper species selection are biological influences that also play into the decisions of the producers. In addition, the trend towards shelterbelt removal as a new innovation through channels similar to innovation adoption paradigm is a major barrier that policy will need to overcome, particularly in regards to the early adopters who are actively removing shelterbelts and who are being actively observed by the late adopters. Increased shelterbelt removal in recent years and the variety of challenges and motivations for removal that producers face will be barriers to future policy aimed at encouraging further shelterbelt adoption and continued retention within the landscape. Producers face a variety of choices and opportunity costs associated with both keeping/maintaining shelterbelts, removing shelterbelts, or planting new ones.

Direct impacts to production, such as overlap of seeding/spraying, large equipment, and detrimental impacts on soils and crops from shelterbelts, are economic type of impacts that need to be considered. Providing incentives to maintain and to encourage additional planting of shelterbelt may help to encourage producers and land owners to incorporate or keep shelterbelts in their operations. These types of policies could benefit many producers (i.e., through payments or tax breaks) and society (i.e., through ecological goods and service provision) and could help to minimize some of the barriers discussed in relation to production efficiencies, age, tenure, and operation type. The heavy front end investment associated with shelterbelt planting and maintenance is a potential barrier to adoption for producers and policy directed at reducing the costs associated with implementation of new shelterbelts and maintenance of existing shelterbelts could help to reduce the impact that this barrier has on producer's decisions.

Organic producers actively recognizing the benefits of shelterbelts and policy aimed at encouraging additional shelterbelts or shelterbelt retention may induce this group to continue using shelterbelts and adopt more. Additional education and awareness about the ecological and landscape level benefits of retaining these buffers and natural lands should be included in policy and extension activities as these types of benefits were not well identified or valued. Additional programs, policy, education, and support is necessary so as to maintain and increase the amount of shelterbelts in the landscape for the benefit of the ecosystem and society as a whole and targeting policy towards groups, such as organic producers, that recognize benefits in their operations may have increased success.

Additional education, outreach and policy developments are needed in regard to these types of strategies to reach the farm unit level. Education about drought preparedness, climate change adaptation, and landscape level impacts all related to shelterbelts use and management in the landscape are some of the areas where policy development can have an impact on farm level management decisions. Using policy instruments to attribute economic value to social and environmental services will be an important tool to encourage sound management practices to be adopted at the farm level. Policy aimed at encouraging additional livestock specific shelterbelts will need to educate producers on proper species selection and management related to fencing as well as include provisions to reduce the costs associated with the implementation of these types of shelterbelts in order to benefit both the producers, general public, and the ecosystem.

In addition to education related specifically to shelterbelts, education for producers on natural reforestation and the use of natural buffer strips in their operations to save on planting and maintenance costs may help to improve the adoption and retention of trees in the landscape in the long term. Additional promotion of preservation of natural and riparian buffers through policy incentives could improve the ecological integrity of agricultural landscapes and provide benefits to society. Policy development aimed at encouraging the retention and further reforestation of these sensitive areas for ecological protection will have to be regionally specific to areas where natural reforestation and natural bush exist. Furthermore, policy aimed at education surrounding effective shelterbelt design specifically to protect waterways and water sources may also be better received by this group of producers than producers in other Soil Zones. In 2014, the Federal government, through the Lake Winnipeg Stewardship Fund, announced $4,000 dollars for workshops in the Carrot River Region of Saskatchewan (Black Soil Zone) for topics related to riparian awareness and education (Environment Canada, 2014). Finally, future policy initiatives directed at shelterbelt retention, adoption, riparian buffers, and natural reforestation will need to recognize and include the challenges such as species selection, climate challenges, lack of extension activities, and inadequate information about shelterbelts as well as provide a significant educational component.

For the area related to the ecological goods and services provided by shelterbelts, any policy development aimed at education and creating awareness should have a component both for producers and the general public. Educational and awareness campaigns related to the ecological significance of shelterbelts will be imperative to the future success of the shelterbelt policy. If shelterbelts are to be included in strategic ecological/environmental management plans, particularly aimed at climate change, producers will need to recognize their importance for their operations.

Policy development designed to specifically encourage additional shelterbelts and shelterbelt retention will need to consider the different impacts for different types of shelterbelts, for different types of operations, and for different types of producers as these factors will influence the success of programs and policy. For these producers education and cost/negative impact reduction will be important factors in their decisions related to shelterbelts. Learning and building off past successful programs, policies, and initiatives will be important moving forward to encourage the retention and adoption of more field shelterbelts within the changing landscape of prairie agriculture. Increasing knowledge and understanding should be considered moving forward in light of the reduced support and extension services that producers have access to (in regards to shelterbelts) as the amount of utility received by producers may not be enough in the long term to sustain the socially optimal level of shelterbelts in the prairies.

Going forward, policy will need to recognize and address that there is some disconnect between economic and environmental/social impacts of shelterbelts. This idea that there is this disconnect between the economic impacts and the positive benefits of shelterbelts should be taken into consideration when designing policy regarding the benefits/costs and impacts of shelterbelts. Overcoming and addressing negative impacts associated with shelterbelts will be a challenge but necessary for policy to be effective at encouraging those who do not currently have shelterbelts to adopt them within their operations. Policy aimed at reducing removal and encouraging retention and adoption will need to be cognizant of how these two producer groups think about and make decisions related to shelterbelts. Overall, producers could benefit from educational campaigns to heighten the understanding of the ecological significance of shelterbelts as well as the potential risk abatement that shelterbelts could provide under various climate change scenarios.

In conclusion, the roles that shelterbelts play in agricultural landscapes are changing. Understanding the full suite of benefits associated with shelterbelts in these landscapes is imperative both from a policy and management perspective. Overall, producers are not aware of the full suite of long term and landscape level benefits that shelterbelts provide within their production systems as well as the benefits to society and the landscape as a whole. In order to encourage future adoption and retention a more robust understanding and value emphasis needs to be placed on environmentally sound agricultural practices in order to maintain ecosystem function and reduce agronomic risk. Shelterbelts should remain an important aspect of environmentally sound best management practices for agriculture and policy should be designed and implemented to reflect the important role shelterbelts play in and could play in greenhouse gas mitigation, provisioning of ecological goods and services, and risk abatement.

8. Conclusion

The insights gained through this analysis will be important for future regionally specific policy aimed at encouraging shelterbelt use and maintenance within the prairies. The research is also important to guide future research in a way that is relevant to producers and prairie agriculture. It was determined that the random sample[23] (additional information on the sampling methods can be reviewed in Appendix F) included in the research was representative of the farm specific population data from the 2011 census.

Shelterbelts provide many benefits to society but many of these benefits are not fully recognized or understood by prairie producers. In addition, the majority of the costs associated with shelterbelt implementation, maintenance, and retention are borne by the private land owner. Changes in the scale of production and production technologies have resulted in a shift in the attitudes of producers related to shelterbelts so that many producers feel that shelterbelts are no longer an important or necessary aspect of agricultural production. Producers face many challenges and make many decisions that impact not only their own production efficiencies but also the entire ecosystems in which they collectively operate; however, this research concludes that many producers are not well informed on the landscape level and ecological services that their shelterbelts provide.

Overall, shelterbelts continue to be very important around the farmyards and infrastructure (i.e., grain bins, equipment) on the prairies. Producers are very well informed about their farmyard shelterbelts; however, as farms grow larger and rural populations decline so too will farmyard shelterbelts. This combined with prevailing attitudes towards field shelterbelts is a concern from an ecological and greenhouse gas balance perspective. These findings suggest that people place greater value on shelterbelts around their homes than in other places. In order to encourage further adoption and retention a way to increase the value of other types of shelterbelts is imperative. This research indicated that there has been a significant increase in shelterbelt removal in recent years. This trend towards more shelterbelt removal in recent years is concerning from an ecological and environmental standpoint.

[23] Additional information on the sampling methods can be reviewed in Appendix F which contains personal communication from Beyhan Amichev who designed and selected the sample

The decision making by farmers in Saskatchewan regarding whether to maintain or remove shelterbelts appears to be largely dependent on their perception of current and future costs and benefits. In many cases producers removed shelterbelts for economic gains associated with crop production and to acquire more land (particularly as land values increase, as this is a way to expand acres without purchasing more land) and to improve field efficiencies (i.e., less time in field, or less overlap). This indicates that in their decision making, social and environmental benefits are not emphasized or considered to be greater than the costs. As a result the total value of shelterbelts (including value to society) to them (privately) is underestimated. This highlights the need for producers to be made more aware of the full range of benefits from shelterbelts.

Shelterbelts generate some private benefits to producers such as improved production through soil protection; however, many of the producers in Saskatchewan are shifting from shelterbelts to other developments/technology for large scale agriculture operations (i.e., zero till, chemical fallow, among others). This research indicates that non-adopters in particular and those removing shelterbelts think that there is no longer the need for the services provided from shelterbelts. Although technological changes are now providing less soil disturbances (and help prevent soil erosion), these new practices can increase the environmental risks and costs (i.e., pesticide resistance, loss of biodiversity, increases disease pressure) in the long term and under future climate change.

It should be recognized that producers face many challenges and trade-offs in managing their land. Collectively agricultural producer's management decisions have landscape level impacts. Producers who do have a more broad understanding of the impacts of their activities may also be more likely to adopt environmental best management practices such as shelterbelts in their operations. For example, the loss of biodiversity, land conversion to annual crops, and increased dependence on agricultural chemical use may increase short-term gains (i.e., higher yields) at the risk or expense of future losses (i.e., disease event, extreme climate event) that the presence of shelterbelts in the landscape may help to minimize or negate. Many producers are not aware of the long-term or large-scale impacts of individual land management decisions. Those producers who have a more robust understanding of costs and benefits and include long-term benefits in their decision making processes are more likely to maintain and adopt shelterbelts in their operations. Continued education and awareness surrounding the full suite of benefits associated with shelterbelts in agricultural landscapes is needed.

In conclusion, shelterbelts are still an important albeit undervalued agronomic practice for reducing risk associated with continuous mono-culture cropping, particularly in the face of climatic uncertainty on the prairies. The current trend towards accelerated shelterbelt removal in agricultural landscapes is concerning.

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10 Appendices

Appendix A- Blank Copy of the 2013 Survey of Producers

Part I

1. What type of operation do you have?

☐ Crop ☐ Livestock ☐ Mixed ☐ Other: _______________

2. What is the size of your farm operation? (number of acres) ________________

3. How many of these acres are rented or leased? _______________

4. Is there a livestock enterprise on your farm?

☐ Yes ☐ No

If yes, what type of livestock do you have? Fill in all that apply

	Dairy	Hogs	Cattle	Poultry	Horses	Other:
Number of animals						

5. Is there commercial crop production on your farm?

☐ Yes ☐ No

Please indicate the types of crops you currently grow and the acres of each in the following table.

Crop	Check all that apply
Hard Wheat	
Soft Wheat	
Barley	
Alfalfa (hay)	
Flax	
Canola	
Lentils	
Peas	
Other:	

6. Does your operation include organic production?

☐ Yes ☐ No

7. Do you use irrigation on your operation?

☐ Yes ☐ No

8. Do you belong to any agricultural organizations?

☐ Yes ☐ No

If yes, please list those that you actively participate in:

____

9. When you require information on agricultural matters, where do you get it from? Check all that apply.

☐ Farm radio ☐ Internet
☐ Agricultural publications ☐ Agricultural industry representatives
☐ Government extension representatives ☐ Other Farmers

☐ Other, specify ________________________________

10. Do you have shelterbelts on you farm?

☐ Yes ☐ No

a) How old are the shelterbelts on your farm? ___________

b) What type of shelterbelts do you have on your farm?

☐ Farm yard shelterbelts ☐ Field shelterbelts
☐ Shelterbelts for livestock ☐ Riparian shelterbelts (around water bodies/streams)
☐ Other:______________

11. How do you feel about the closure of the tree nursery at Indian Head and how will it affect you?

____
____
____
____
____

12. Please complete the following questions regarding your shelterbelts. Your best estimate is acceptable for cost information. Please fill out this section to the best of your knowledge. Question A) relates to farmyard shelterbelts, and B) to field/livestock shelterbelts. Question C) relates to any benefits you receive from any of your shelterbelts.

Only answer the questions that apply to you.

A) For your farmyard shelterbelts.

i) What is the size of the shelterbelt? ___________

ii) How many rows? _________________________

iii) What species are included in your shelterbelt?

____

iv) What have you done to prepare the site to plant your shelterbelt?

____

____

v) How did you plant your shelterbelt?

____

____

vi) What were the costs to you associated with the preparation and planting activities?

Fuel (litres):_________ Labour(hours): __________ Equipment:__________ Chemical : ____________ Other:__________________

vii) What have you done to maintain your shelterbelts?

____

____

viii) How many years have you maintained your shelterbelt on an annual basis? ____________

ix) What were the costs to you of these maintenance activities?

Fuel (litres): ___________ Labour (hours): _________ Equipment: _____________
Pesticide/Herbicide: _________ Watering: __________ Fertilizer: ________
Other:______________

x) What activities have you done to renovate your shelterbelt and what were the costs to you?

____

____

Labour: _________ New trees: __________ Chemical: _____________

Equipment:___________ Fuel: ___________ Other:__________________

xi) Describe what activities you have done to remove your shelterbelts?

____

____

xii) What were the costs to you associated with these removal activities?

Tree removal: ____________ Labour: _______________

Equipment cost: ___________ Fuel: _________________

Chemical Treatment:__________________ Other: ______________

xiii) Why did you remove these shelterbelts? When did you remove these shelterbelts?

____
____

xiv) Please describe any other costs you have had related to you shelterbelt:

____
____
___

xv) Comments:

____
____
____

B) For your **Field and/or Livestock Shelterbelt.**

i) What is the size of the shelterbelt? __________
ii) How many rows? ______________________
iii) What species?____

iv) What have you done to prepare the site to plant your shelterbelt?

____

____

v) How did you plant your shelterbelt?

____

____

vi) What were the costs to you associated with the preparation and planting activities?

Fuel (litres): __________ Labour (hours):_________ Equipment: ___________
Chemical : _________ Other:__________

vii) What have you done to maintain these shelterbelt(s)?

____

____

____

viii) How many years did you maintain your shelterbelt on an annual basis? ___________

ix) What were the costs to you of the maintenance activities?

Fuel (litres): __________ Labour (hours): ________ Equipment: ____________
Pesticide/Herbicide: ________ Watering: _________ Fertilizer: _______
Other:_____________

x) What activities have you done to renovate your shelterbelt and what were the costs to you?

____

____

Labour: _________ New trees: __________ Chemical: _____________

Equipment:___________ Fuel: ___________ Other:__________________

xi) Describe what activities you have done to remove your shelterbelts?

____

____

xii) What were the costs to you associated with these removal activities?

Tree removal: ____________ Labour: _______________

Equipment cost: ___________ Fuel: _________________

Chemical Treatment:__________________ Other: ______________

xiii) Why did you remove these shelterbelts? When did you remove these shelterbelts?

____

____

xiv) Please describe any other costs you have had related to you shelterbelt:

____

____

____

xv) Comments:

____

____

C) What benefits do you receive from your shelterbelts (List all that apply)?

____

____

____

____

____

13. Have you ever considered planting more shelterbelts?

☐ Yes ☐ No

14. Do you plan on including shelterbelts as a part of your agricultural management plans in the future (i.e., continuing to include them or planting them in the future)?

☐ Yes ☐ No ☐ Uncertain

15. Do you feel that there is adequate information available regarding the costs and benefits of using shelterbelts in your operation?

☐ Yes ☐ No ☐ Uncertain

16. I consider my neighbour's decisions to have a ___________ influence on me.

☐ Very Strong ☐ Strong ☐ Some ☐ Minimal ☐ None

17. For the following questions please indicate how you view the following factors related to shelterbelts.

Shelterbelts impact on crop yields.
- ☐ Highly Negative
- ☐ Negative
- ☐ Neutral
- ☐ Positive
- ☐ Highly Positive

The establishment and maintenance costs.
- ☐ Very High
- ☐ High
- ☐ Neutral
- ☐ Small
- ☐ Very Small

Using shelterbelts to improve irrigation efficiency.
- ☐ Highly Negative
- ☐ Negative
- ☐ Neutral
- ☐ Positive
- ☐ Highly Positive

Using shelterbelts to reduce pesticide drift
- ☐ Highly Negative
- ☐ Negative
- ☐ Neutral
- ☐ Positive
- ☐ Highly Positive

Taking land out of agricultural production.
- ☐ Highly Negative
- ☐ Negative
- ☐ Neutral
- ☐ Positive
- ☐ Highly Positive

Agricultural crop prices have ________ impact on if I will include shelterbelts.
- ☐ Highly
- ☐ Negative
- ☐ Neutral

☐ Positive
☐ Highly Positive

Shelterbelts reducing soil erosion from wind and water.
☐ Highly Negative
☐ Negative
☐ Neutral
☐ Positive
☐ Highly Positive

Improved moisture for my crops through snow capture by shelterbelts.
☐ Highly Negative
☐ Negative
☐ Neutral
☐ Positive
☐ Highly Positive

Shelterbelts reducing wind damage to crops.
☐ Highly Negative
☐ Negative
☐ Neutral
☐ Positive
☐ Highly Positive

Changes to the microclimate (i.e., lower evapotranspiration, cooler daytime/warmer night time temperatures) near shelterbelts.
☐ Highly Negative
☐ Negative
☐ Neutral
☐ Positive
☐ Highly Positive

Overlapping of seeding/spraying operations around shelterbelts.
☐ Highly Negative
☐ Negative
☐ Neutral
☐ Positive
☐ Highly Positive

Providing livestock protection and reducing livestock death.
☐ Highly Negative
☐ Negative
☐ Neutral
☐ Positive
☐ Highly Positive

Improved livestock feed/water use efficiency from shelterbelt protection.
☐ Highly Negative
☐ Negative
☐ Neutral
☐ Positive
☐ Highly Positive

Odour mitigation (i.e., from swine) by shelterbelts.
☐ Highly Negative
☐ Negative

- ☐ Neutral
- ☐ Positive
- ☐ Highly Positive

Reduced wind speeds and shelter around my home from shelterbelts.

- ☐ Highly Negative
- ☐ Negative
- ☐ Neutral
- ☐ Positive
- ☐ Highly Positive

The protection of buildings and farm infrastructure from shelterbelts.

- ☐ Highly Negative
- ☐ Negative
- ☐ Neutral
- ☐ Positive
- ☐ Highly Positive

Beautification of my farmyard through the use of shelterbelts.

- ☐ Highly Negative
- ☐ Negative
- ☐ Neutral
- ☐ Positive
- ☐ Highly Positive

Improved air quality from shelterbelts.

- ☐ Highly Negative
- ☐ Negative
- ☐ Neutral
- ☐ Positive
- ☐ Highly Positive

Protection of water sources through shelterbelts/buffers around streams, riparian, and shoreline areas.

- ☐ Highly Negative
- ☐ Negative
- ☐ Neutral
- ☐ Positive
- ☐ Highly Positive

Protection of and provision of wildlife habitat in shelterbelts.

- ☐ Highly Negative
- ☐ Negative
- ☐ Neutral
- ☐ Positive
- ☐ Highly Positive

Enhancement of natural insects, such as pollinators, through shelterbelt habitat.

- ☐ Highly Negative
- ☐ Negative
- ☐ Neutral
- ☐ Positive
- ☐ Highly Positive

Species biodiversity in shelterbelts in agricultural landscapes.

- ☐ Highly Negative
- ☐ Negative
- ☐ Neutral

☐ Positive
☐ Highly Positive
☐

Using shelterbelts as a part of a sustainable agricultural production system.

☐ Highly Negative
☐ Negative
☐ Neutral
☐ Positive
☐ Highly Positive

Carbon sequestration through trees in shelterbelts.

☐ Highly Negative
☐ Negative
☐ Neutral
☐ Positive
☐ Highly Positive

Shelterbelts influence on land values.

☐ Highly Negative
☐ Negative
☐ Neutral
☐ Positive
☐ Highly Positive

Using shelterbelts to capture snow for dugouts.

☐ Highly Negative
☐ Negative
☐ Neutral
☐ Positive
☐ Highly Positive

Part II

The information requested in this section is very important to our analysis of the questionnaire. We hope that asking for ranges will make it easier for you to answer this section. Please be assured that this information, like that in the rest of the questionnaire is strictly confidential.

12. What is your age? _______ (years)

13. What is your gender?

☐ Male ☐ Female

14. How many years have you been farming, since the age of 18? ________ (years)

15. What is the highest level of education that you have completed?

Elementary school (0-6 years) ☐

Junior high school (7-9 years) ☐

High School (10-12 years) ☐

Technical diploma ☐

University ☐

16. What is the legal land description of your farm? ___________________________

17. What was the gross farm sales last year? (Check range)

☐ $0-$29,000 ☐ $30,000-59,999 ☐ $60,000-89,999

☐ $ 90,000- 119,999 ☐ $120,000-149,999 ☐ above $150,000

19. As a producer, do you think that the benefits associated with shelterbelts are greater than the costs?

☐ Yes ☐ No ☐ Uncertain

Additional comments and opionions on shelterbelts:

Appendix B- Survey Results for Sample Broken Down by Question
Part I

In this appendix the responses of participants are broken down question by question. Response frequencies and/or number of responses per category are provided in charts or figures. Each question will have a graph or chart highlighting the responses of the entire sample for this question.

1. What type of farming operation do you have?

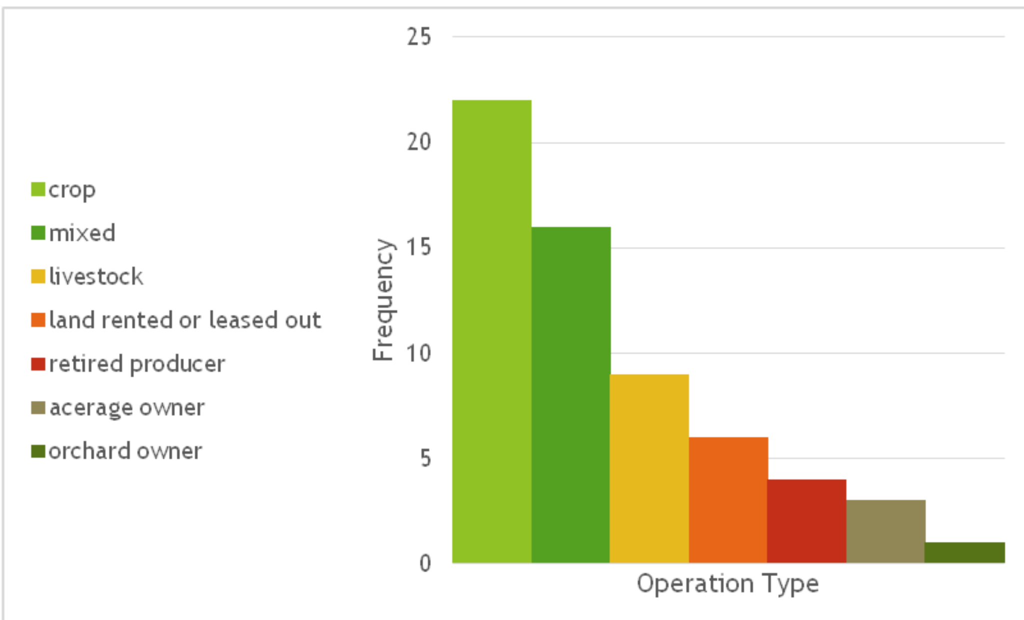

FIGURE B.I.1- RESPONSE INDICATED FOR OPERATION TYPE FOR THE ENTIRE SAMPLE

2. What is the size of your farm operation? (number of acres) _______________

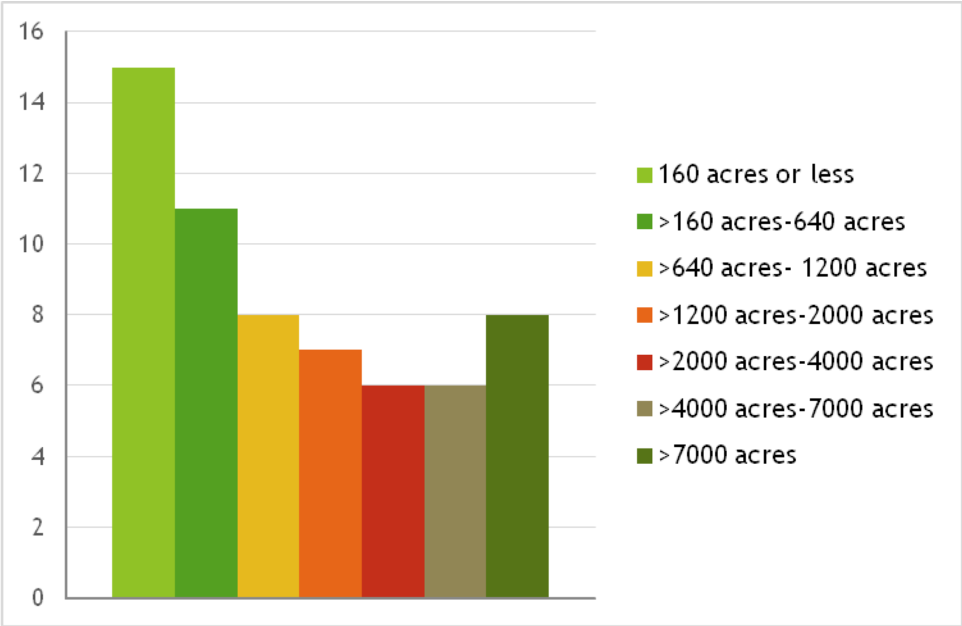

FIGURE B.I.2- RESPONSE FREQUENCY FOR FARM SIZE (IN ACRES) FOR THE SURVEY PARTICIPANTS

3. How many of these acres are rented or leased? _______________

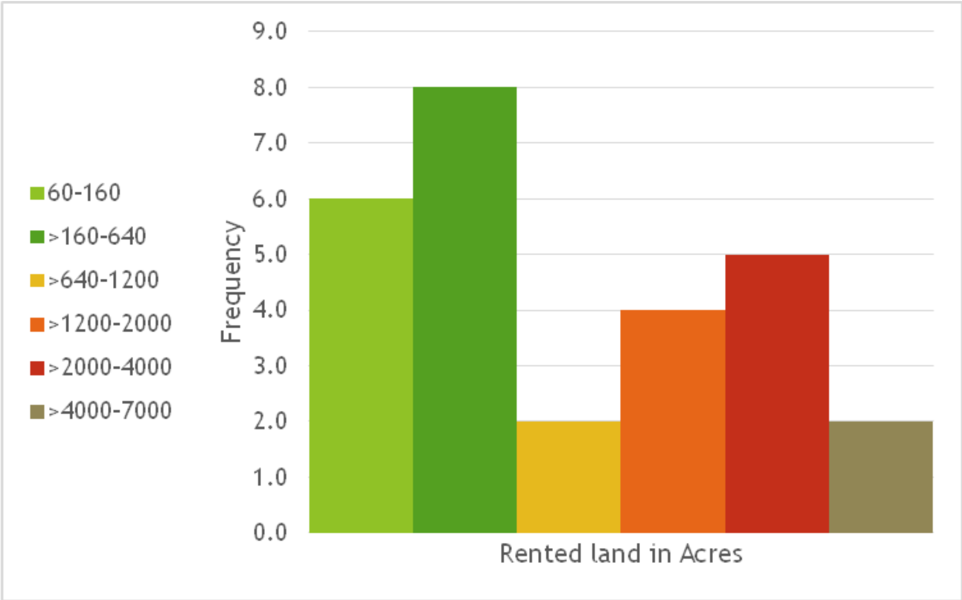

FIGURE B.I.3- RESPONSE FREQUENCY FOR THOSE WHO ARE RENTING OR LEASING LAND FROM OTHERS FOR THE ENTIRE SAMPLE

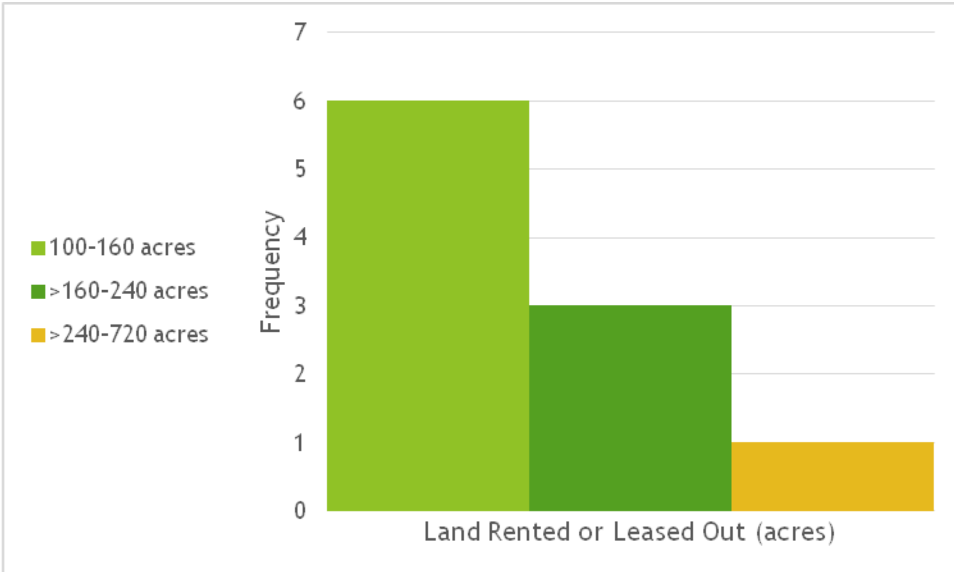

FIGURE B.I.4- RESPONSE FREQUENCY FOR THOSE INDICATING THAT THEY RENT OR LEASE LAND TO OTHERS OUT OF THE ENTIRE SAMPLE

4. Is there a livestock enterprise on your farm?

If yes, what type of livestock do you have? Fill in all that apply

TABLE B.I.1- NUMBER, PERCENTAGE OF TOTAL, AND PERCENTAGE OF MIXED/LIVESTOCK OPERATIONS FOR TYPES OF LIVESTOCK INDICATED IN OPERATIONS FOR THE ENTIRE SAMPLE

	CATTLE	SHEEP/GOATS	POULTRY	HORSES	OTHER
NUMBER INDICATING (X)	20	5	4	8	3
PERCENTAGE OF TOTAL (X/61*100)	33%	8%	7%	13%	5%
PERCENTAGE OF LIVESTOCK/MIXED OPERATIONS (X/25*100)	80%	20%	16%	32%	12%

5. What types of crops are there on your farm?

TABLE B.I.2- TYPES OF CROPS INDICATED BY CROP PRODUCERS WITH NUMBER OF PARTICIPANTS INDICATING, PERCENTAGE OF TOTAL PRODUCERS INDICATING, AND PERCENTAGE OF THE CROPS INDICATED

	CEREALS	PULSES	HAY	OILSEEDS	SPECIALTY	FALLOW
NUMBER INDICATING (X)	42	18	24	34	8	4
PERCENTAGE OF TOTAL PRODUCERS INDICATING (X/61*100)	69%	30%	39%	56%	13%	7%
PERCENTAGE OF CROPS INDICATED TO BE GROWN IN SAMPLE (X/130*100)	32%	14%	19%	26%	6%	3%

6. Does your operation include organic production?

TABLE B.I.3- NUMBER OF ORGANIC AND NON-ORGANIC OPERATIONS IN THE SAMPLE

Particulars		Frequency	Percent
Use of Organic Operations	yes	8	13.1
	no	53	86.9
	Total	61	100.0

7. Do you use irrigation on your operation?

TABLE B.I.4- NUMBER OF OPERATIONS WITH AND WITHOUT IRRIGATION

Particulars		Frequency	Percent
User of Irrigation	yes	2	3.3
	no	59	96.7
	Total	61	100.0

8. Do you belong to any agricultural organizations?

TABLE B.I.5- NUMBER OF RESPONDENTS WHO INDICATED IF THEY ARE IN AGRICULTURAL ORGANIZATIONS FOR THE ENTIRE SAMPLE

Particulars		**Frequency**	**Percent**
Membership in Agricultural Organizations	yes	14	23.0
	no	47	77.0
	Total	61	100.0

If yes, please list those that you actively participate in:

Memberships Indicated Include:

Saskatchewan Association of Rural Municipalities (SARM)
Organic producer association
SOKA
SOD
Ducks Unlimited
R.M. agriculture committee/member **(x4)**
Paradise Valley Agriculture Society
Saskatchewan Cattleman's Association
Farmers of North America
National Farmers Union **(x3)**
Eco Cert
Saskatchewan Institute of Agrologists/Professional Agrologist **(x2)**
Cherry Producers Association
Fruit Growers Association
Border Conservation Group

9. When you require information on agricultural matters, where do you get it from? Check all that apply.

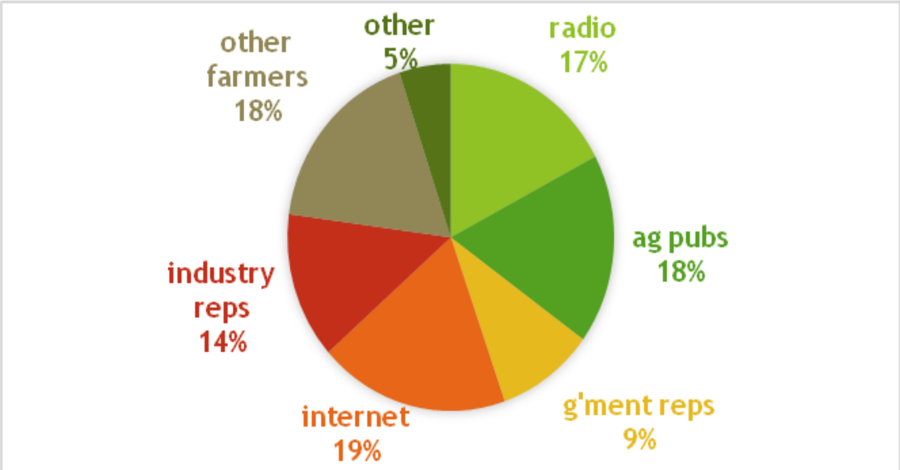

FIGURE B.I.5- SOURCES OF AGRICULTURAL INFORMATION INDICATED BY ENTIRE SAMPLE

TABLE B.I.6- NUMBER OF PARTICIPANTS INDICATING WHETHER THEY DO OR DO NOT USE VARIOUS INFORMATION SOURCES TO GET THEIR AGRICULTURAL INFORMATION ABLE THEY DO OR DO NOT USE VARIOUS INFORMATION

	RADIO	AG PUBS	G'MENT REPS	INTERNET	INDUSTRY REPS	OTHER FARMERS	OTHER
YES	34	35	19	37	27	35	10
NO	27	26	42	24	34	26	51

Do you have shelterbelts on you farm?

shelterbelts_onfarm

		Frequency	Percent	Valid Percent	Cumulative Percent		
Valid	yes		60	98.4	98.4	98.4	
	no			1	1.6	1.6	100.0
Total				**61**	**100.0**	**100.0**	

How old are the shelterbelts on your farm? ___________

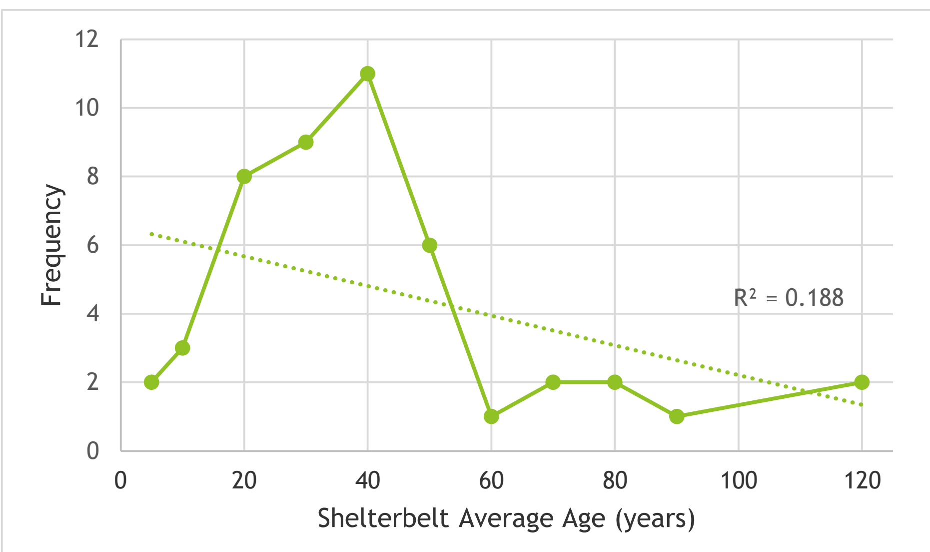

FIGURE B.I.6- AVERAGE AGE OF SHELTERBELTS ON FARM AS INDICATED BY SURVEY PARTICIPANTS

What type of shelterbelts do you have on your farm?

TABLE B.I.7- NUMBER OF PARTICIPANTS INDICATING WHETHER THEY DO OR DO NOT USE VARIOUS INFORMATION SOURCES TO GET THEIR AGRICULTURAL INFORMATION ABLE THEY DO OR DO NOT USE VARIOUS INFORMATION

farmyard_shelterbelt

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	59	96.7	96.7	96.7
	no	2	3.3	3.3	100.0
	Total	61	100.0	100.0	

field_shelterbelt

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	32	52.5	52.5	52.5
	no	29	47.5	47.5	100.0
	Total	61	100.0	100.0	

livestock_shelterbelt

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	16	26.2	26.2	26.2
	no	45	73.8	73.8	100.0
	Total	61	100.0	100.0	

other_shelterbelt

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	15	24.6	24.6	24.6
	no	46	75.4	75.4	100.0
	Total	61	100.0	100.0	

Questions 11 and 12 were analyzed in transcript format. The transcripts are not included in the thesis document to protect the anonymity of the participants. The responses related to costs and benefits are coded and included in Appendix C

10. How do you feel about the closure of the tree nursery at Indian Head and how will it affect you?
11. Please complete the following questions regarding your shelterbelts. Your best estimate is acceptable for cost information. Please fill out this section to the best of your knowledge. <u>Question A) relates to farmyard</u>

shelterbelts, and B) to field/livestock shelterbelts. Question C) relates to any benefits you receive from any of your shelterbelts.

Only answer the questions that apply to you.

12. Have you ever considered planting more shelterbelts?

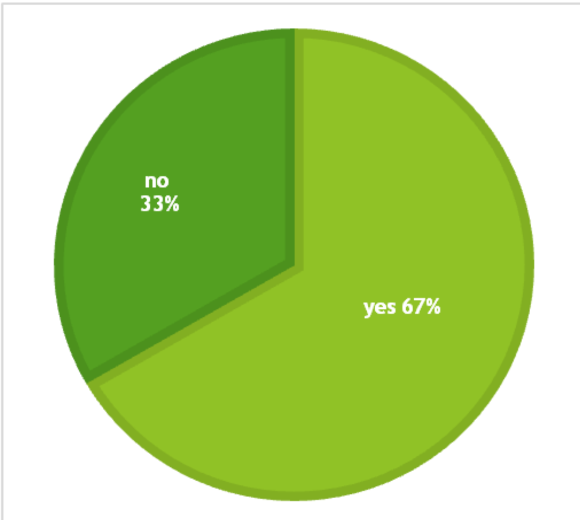

FIGURE B.I.7- PERCENTAGE OF RESPONDENTS INDICATING IF THEY HAVE CONSIDERED PLANTING MORE SHELTERBELTS

13. Do you plan on including shelterbelts as a part of your agricultural management plans in the future (i.e., continuing to include them or planting them in the future)?

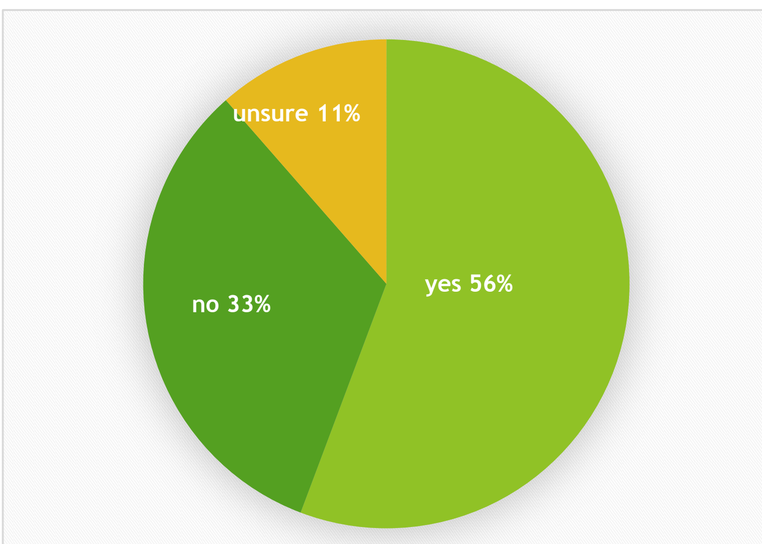

FIGURE B.I.8- PERCENTAGE OF RESPONDENTS INDICATING THEIR PLANS FOR CONTINUED USE OF SHELTERBELTS

14. Do you feel that there is adequate information available regarding the costs and benefits of using shelterbelts in your operation?

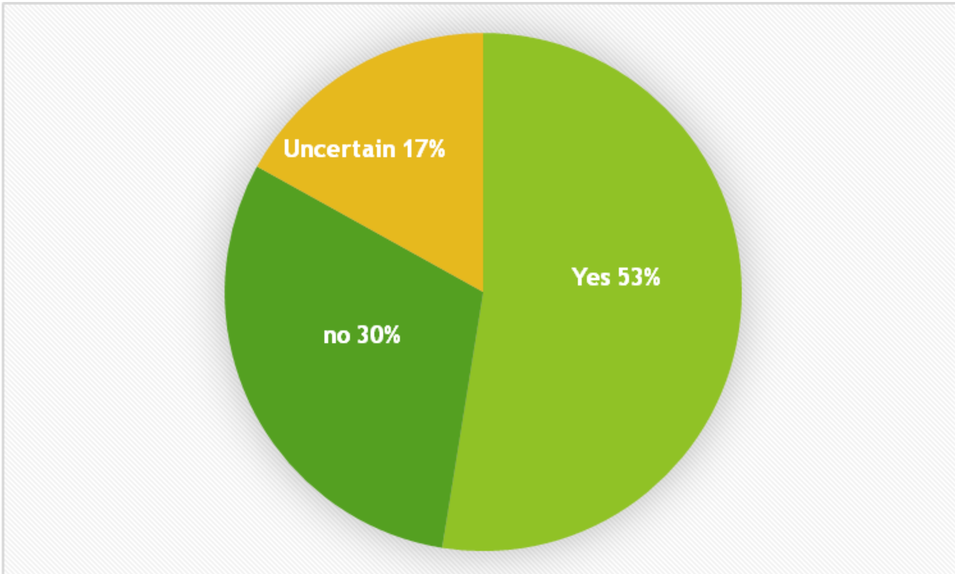

FIGURE B.I.9- PERCENTAGE OF SAMPLE PARTICIPANTS RESPONSES FOR IF ADEQUATE INFORMATION IS AVAILABLE ABOUT SHELTERBELTS

15. I consider my neighbour's decisions to have a ___________ influence on me.

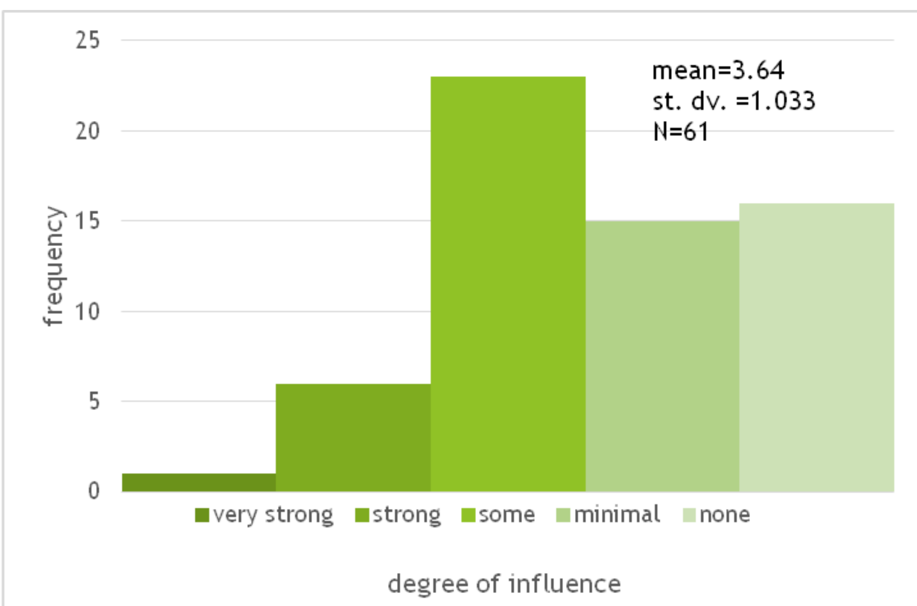

FIGURE B.I.10- DEGREE OF INFLUENCE THAT NEIGHBOURS HAVE ON MANAGEMENT DECISIONS AS INDICATED BY SAMPLE PARTICIPANTS

16. For the following questions please indicate how you view the following factors related to shelterbelts. Refer to Appendix A.1 for the exact wording of the questions for the following factors:

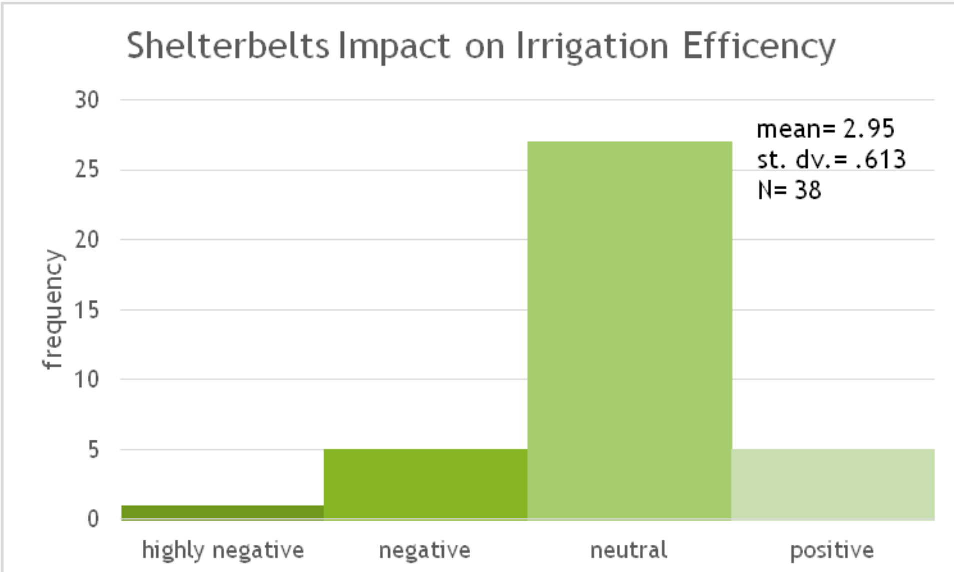

FIGURE B.I.11- SHELTERBELTS IMPACT ON IRRIGATION EFFICIENCY AS INDICATED BY SURVEY PARTICIPANTS

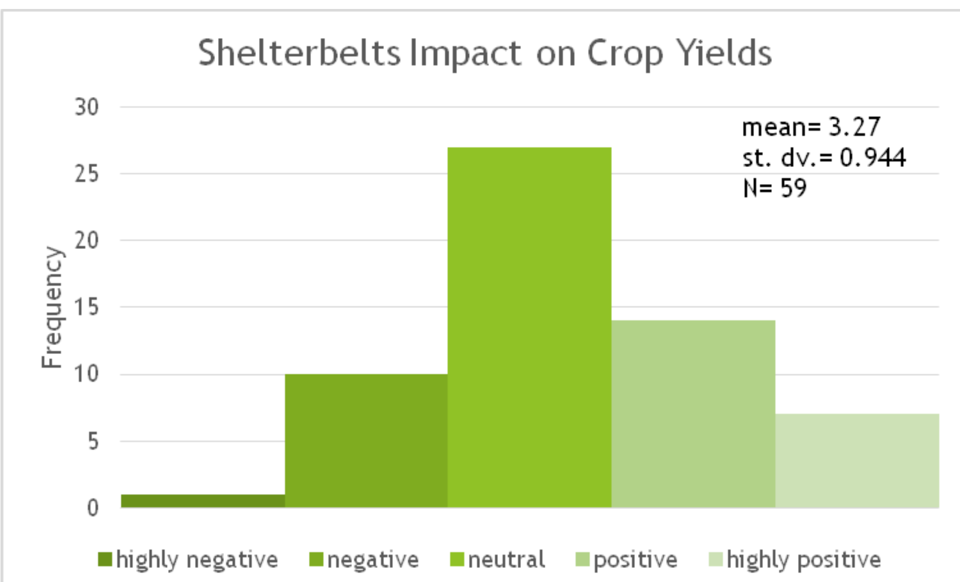

FIGURE B.I.12- SHELTERBELTS IMPACT ON CROP YIELDS AS INDICATED BY SURVEY PARTICIPANTS

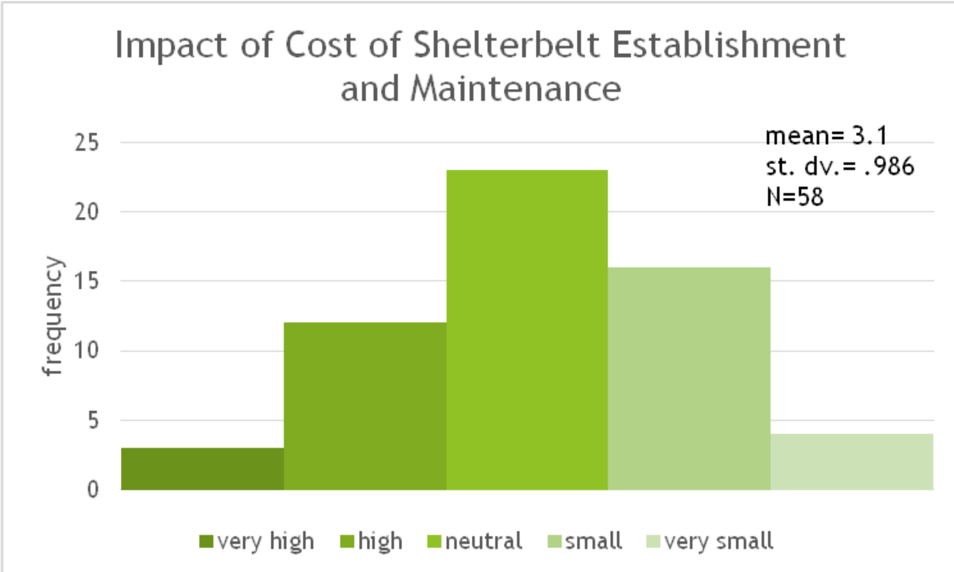

FIGURE B.I.13- AMOUNT OF COSTS ASSOCIATED WITH CURRENT SHELTERBELTS ESTABLISHMENT AND MAINTENANCE AS INDICATED BY SURVEY PARTICIPANTS

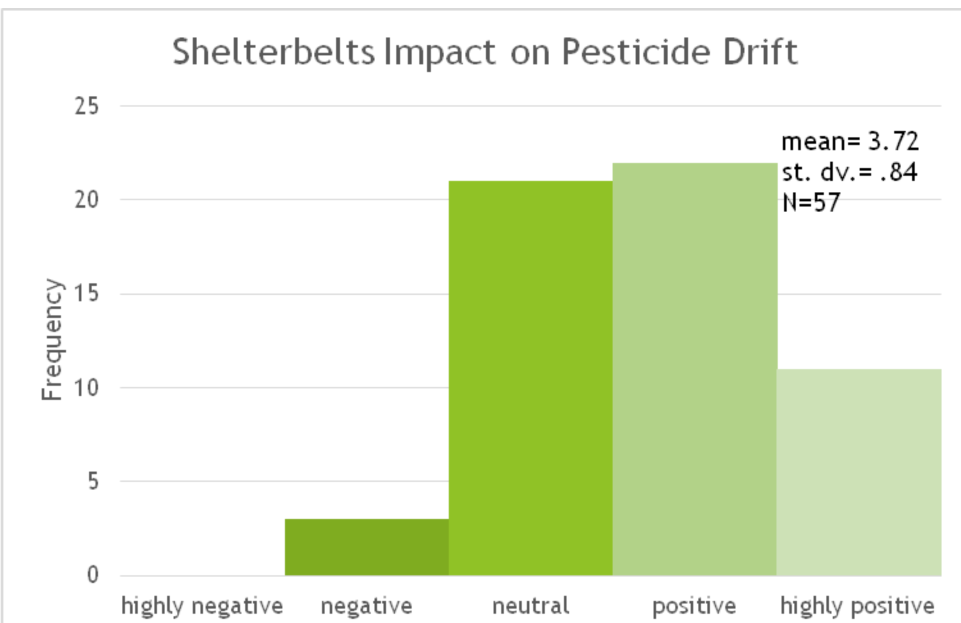

FIGURE B.I.14- THE IMPACT OF SHELTERBELTS ON PESTICIDE DRIFT AS INDICATED BY SURVEY PARTICIPANTS

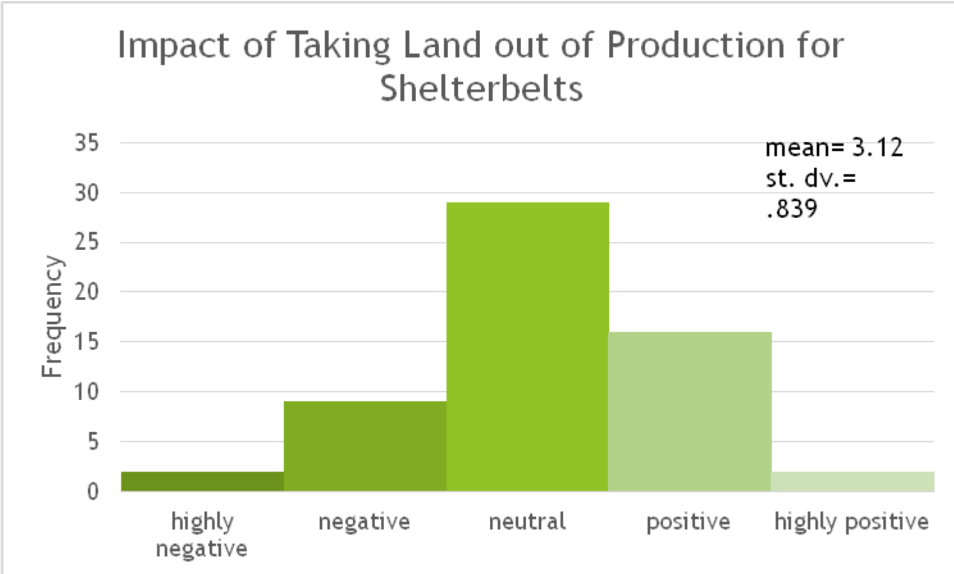

FIGURE B.I.15- THE IMPACT OF TAKING LAND OUT OF PRODUCTION FOR SHELTERBELTS AS INDICATED BY SURVEY PARTICIPANTS

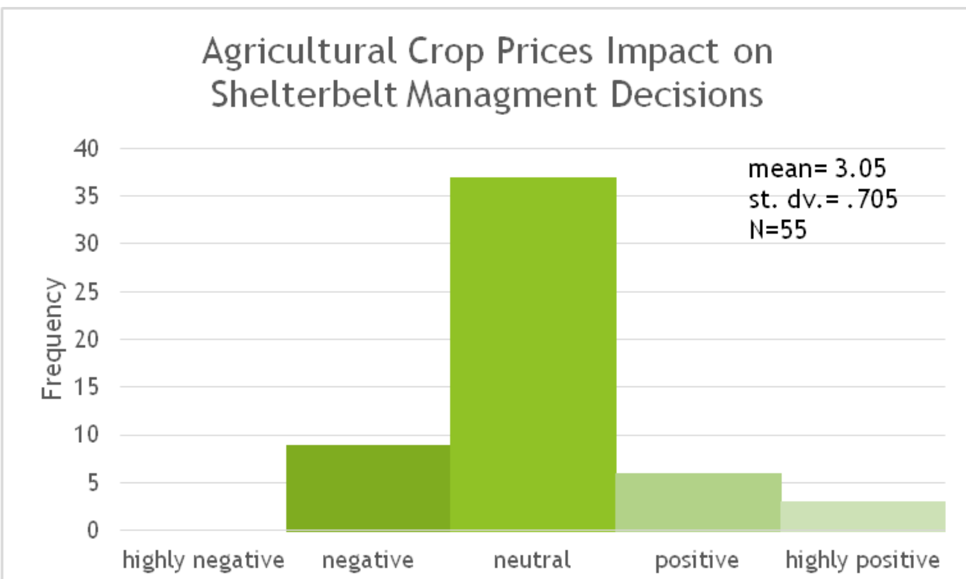

FIGURE B.I.16- THE IMPACT THAT THE PRICES OF OTHER AGRICULTURAL CROPS HAVE ON SHELTERBELT MANAGEMENT DECISIONS AS INDICATED BY SURVEY PARTICIPANTS

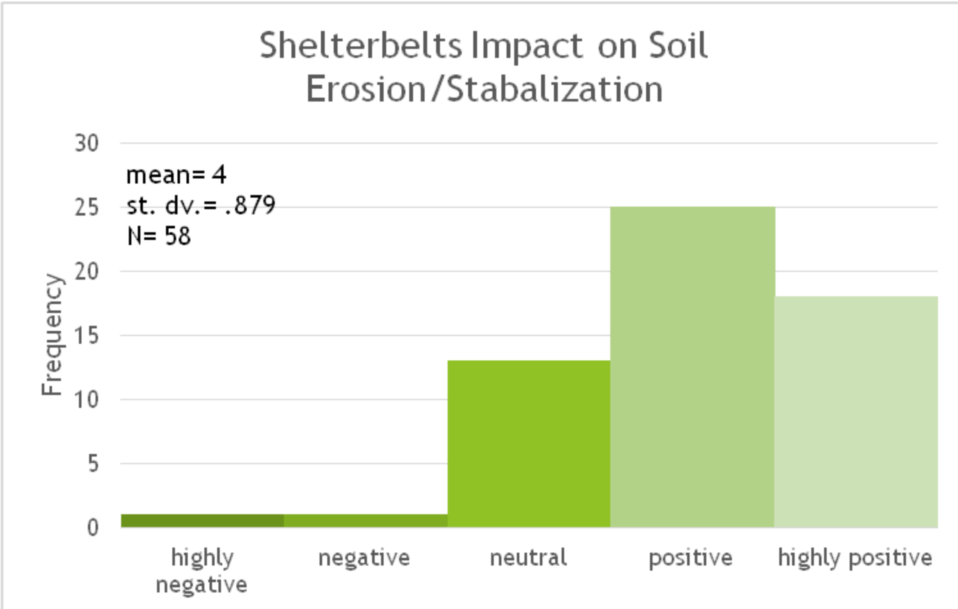

FIGURE B.I.17- SHELTERBELTS IMPACT ON EROSION CONTROL AND SOIL STABILIZATION AS INDICATED BY SURVEY PARTICIPANTS

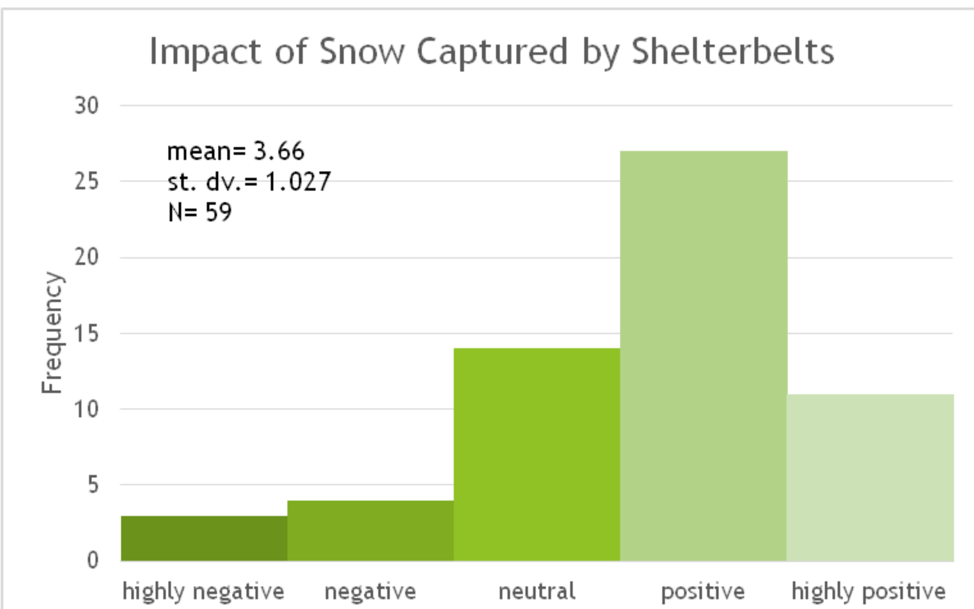

FIGURE B.I.18- IMPACT OF SNOW CAPTURED IN AND BY SHELTERBELTS AS INDICATED BY SURVEY PARTICIPANTS

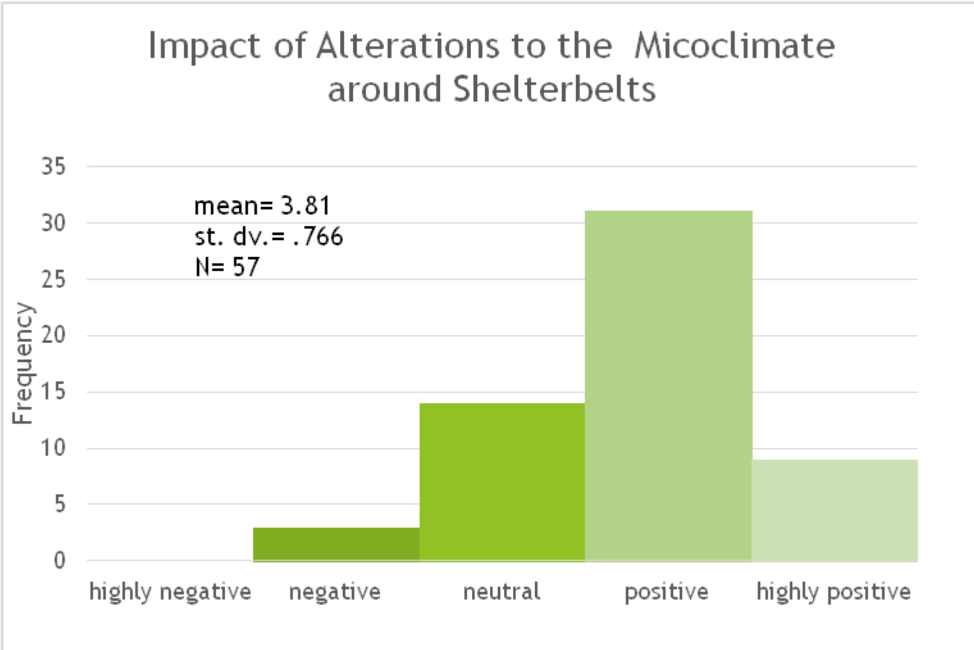

FIGURE B.I.19- IMPACT OF ALTERATIONS TO THE MICROCLIMATE AROUND SHELTERBELTS AS INDICATED BY SURVEY PARTICIPANTS

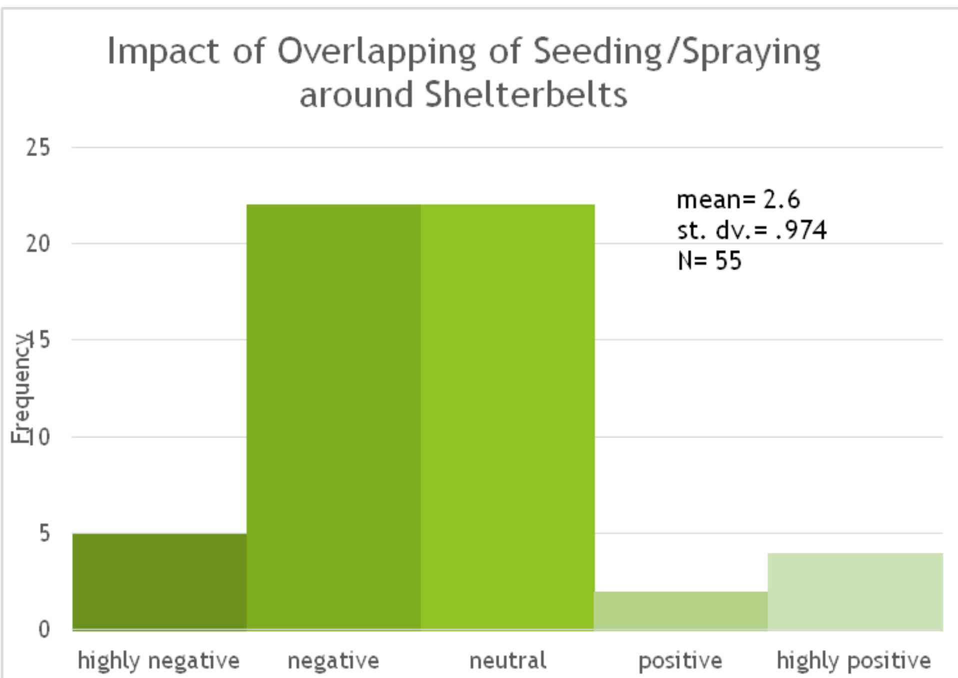

FIGURE B.I.20- IMPACT OF OVERLAPPING OF SEEDING AND SPRAYING AROUND SHELTERBELTS AS INDICATED BY SURVEY PARTICIPANTS

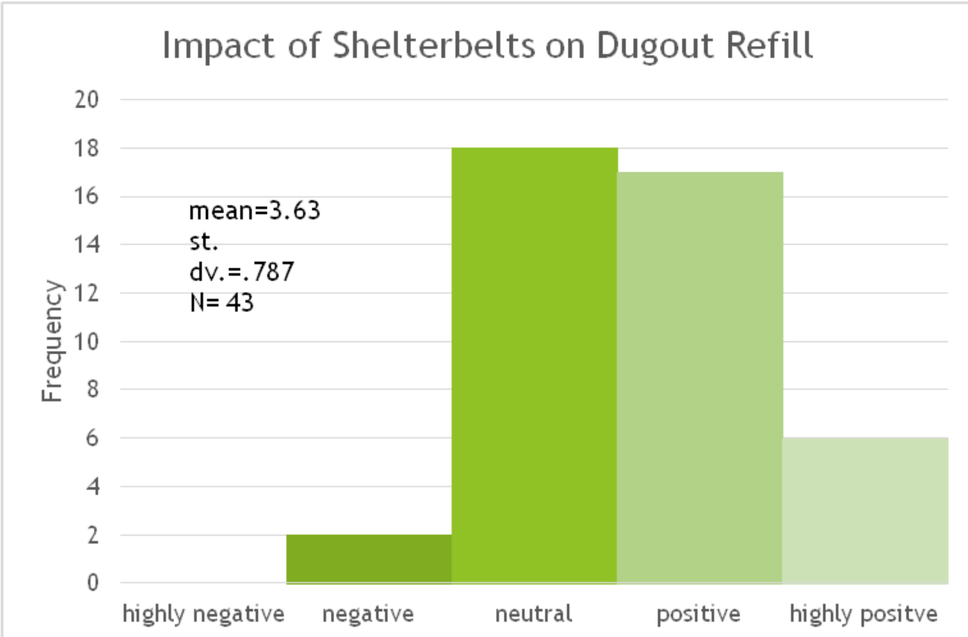

FIGURE B.I.21- IMPACT OF SHELTERBELTS ON DUGOUT FILL AND REFILL AS INDICATED BY SURVEY PARTICIPANTS

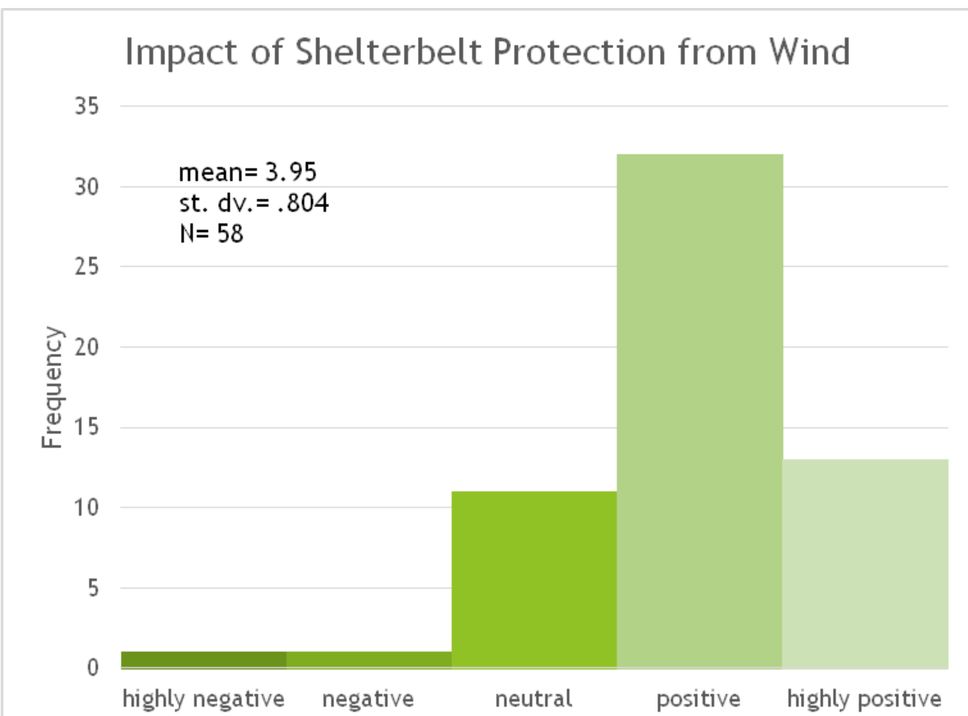

FIGURE B.I.22- IMPACT OF SHELTERBELTS FOR PROTECTION FROM THE WIND AS INDICATED BY SURVEY PARTICIPANTS

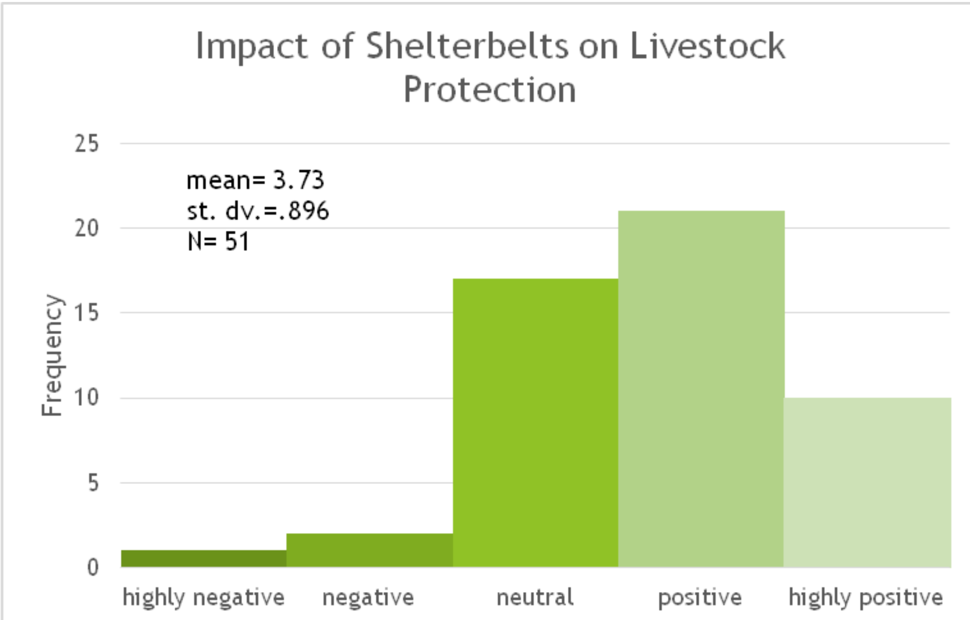

FIGURE B.I.23- IMPACT OF SHELTERBELTS ON PROTECTION FOR LIVESTOCK AS INDICATED BY SURVEY PARTICIPANTS

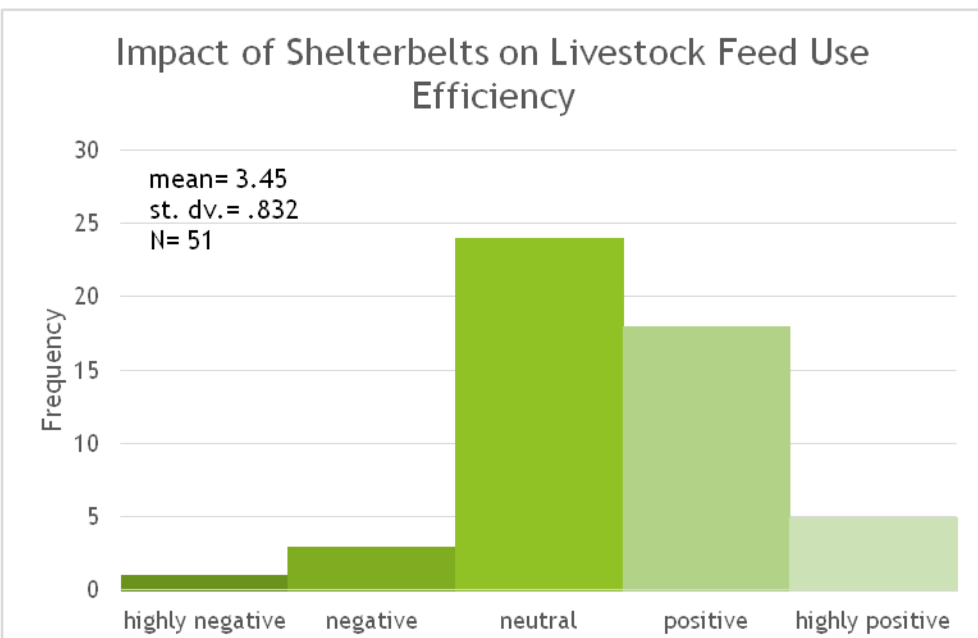

FIGURE B.I.24- IMPACT OF SHELTERBELTS ON LIVESTOCK FEED USE EFFICIENCY AS INDICATED BY SURVEY PARTICIPANTS

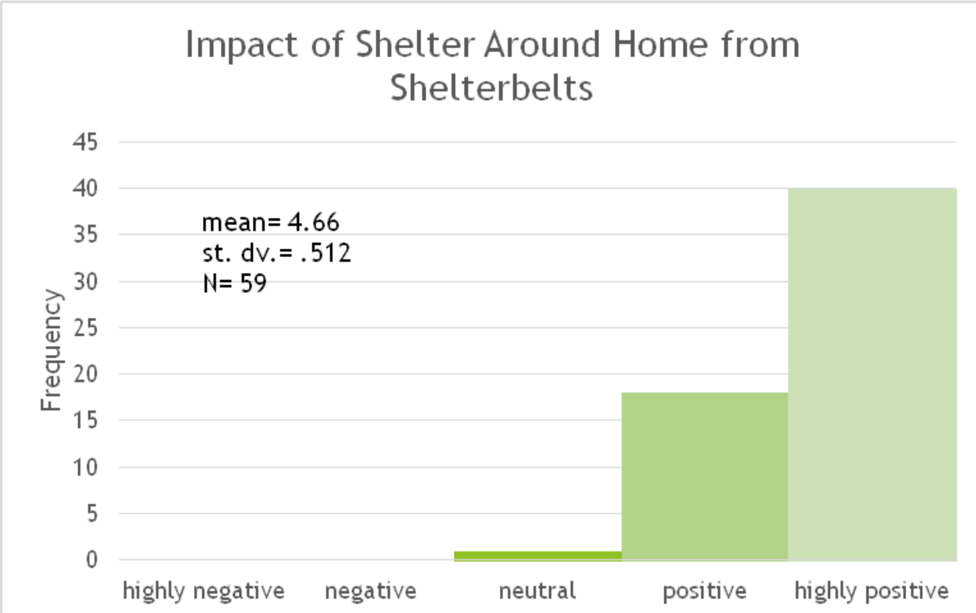

FIGURE B.I.25- IMPACT OF SHELTERBELTS FOR SHELTER AROUND THE FARMYARD AS INDICATED BY SURVEY PARTICIPANTS

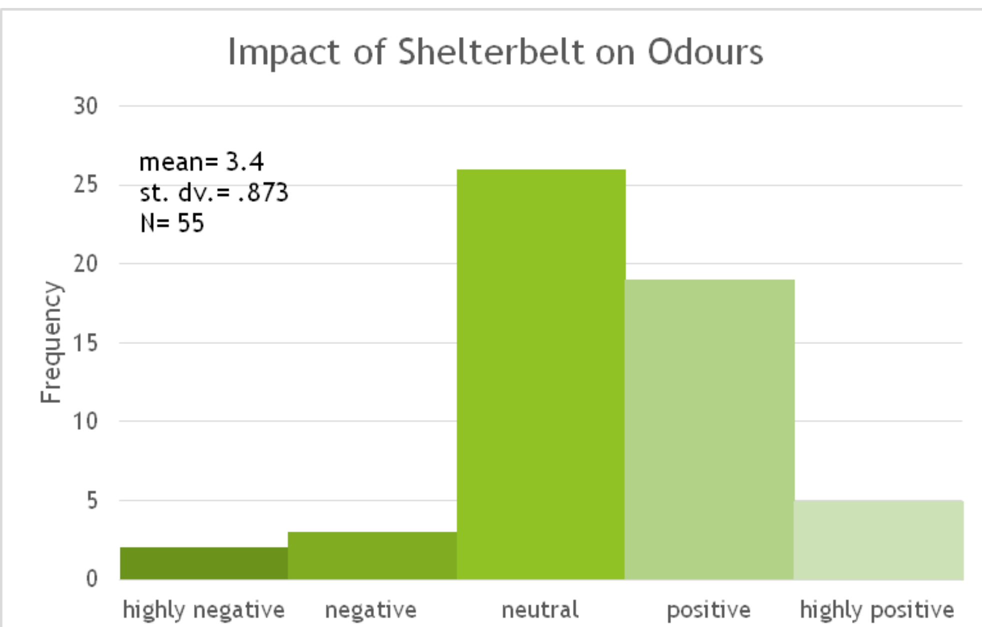

FIGURE B.I.26- IMPACT OF SHELTERBELTS ON ODOURS AS INDICATED BY SURVEY PARTICIPANTS

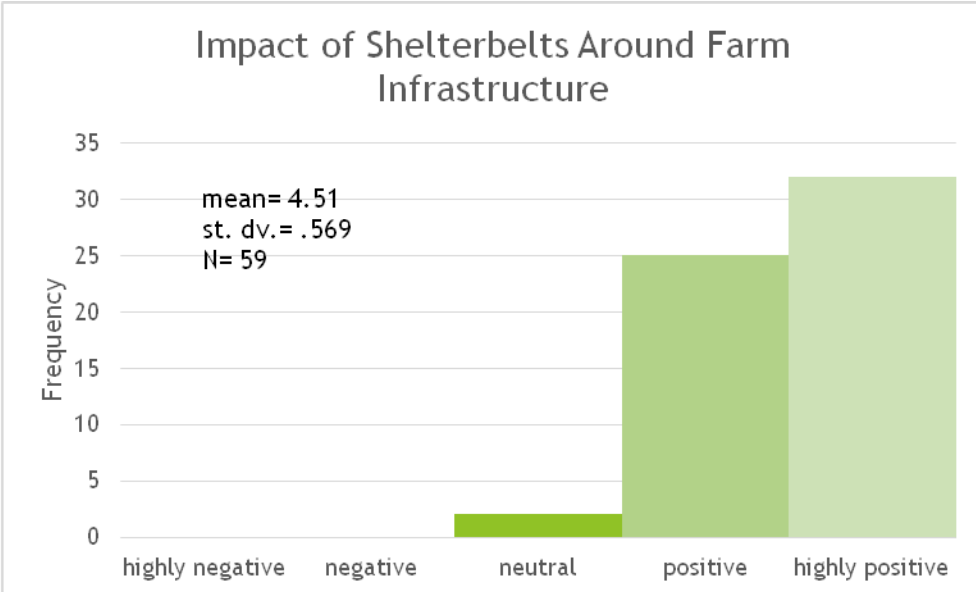

FIGURE B.I.27- IMPACT OF SHELTERBELTS FOR SHELTER OF FARM INFRASTRUCTURE (I.E., BINS) AS INDICATED BY SURVEY PARTICIPANTS

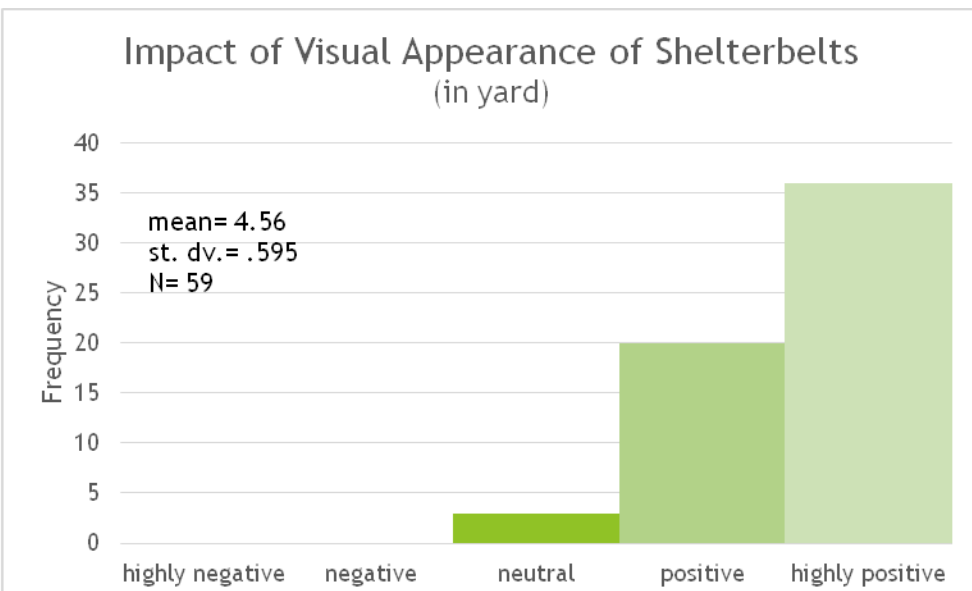

FIGURE B.I.28- IMPACT OF SHELTERBELTS ON VISUAL APPEARANCE OF YARDS AS INDICATED BY SURVEY PARTICIPANTS

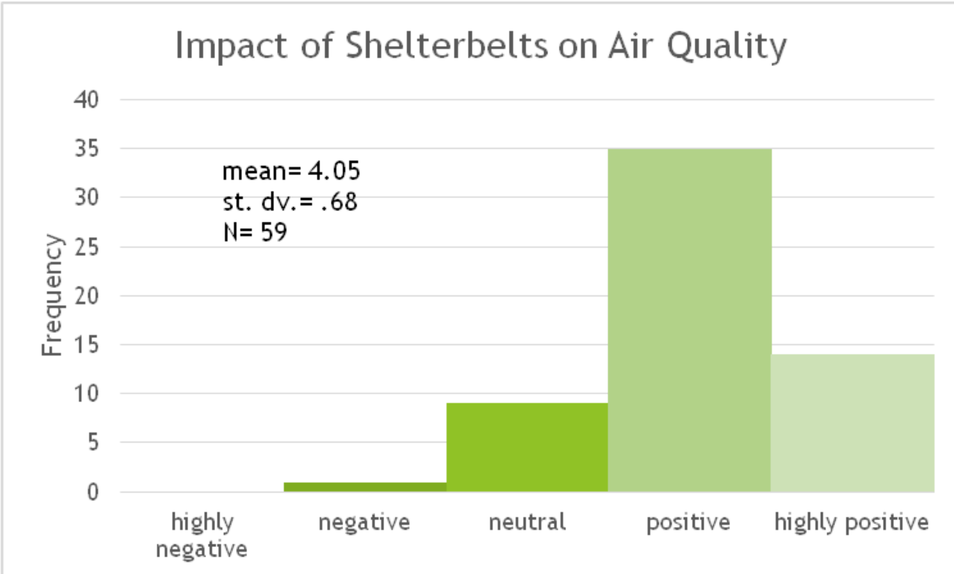

FIGURE B.I.29- IMPACT OF SHELTERBELTS ON AIR QUALITY AS INDICATED BY SURVEY PARTICIPANTS

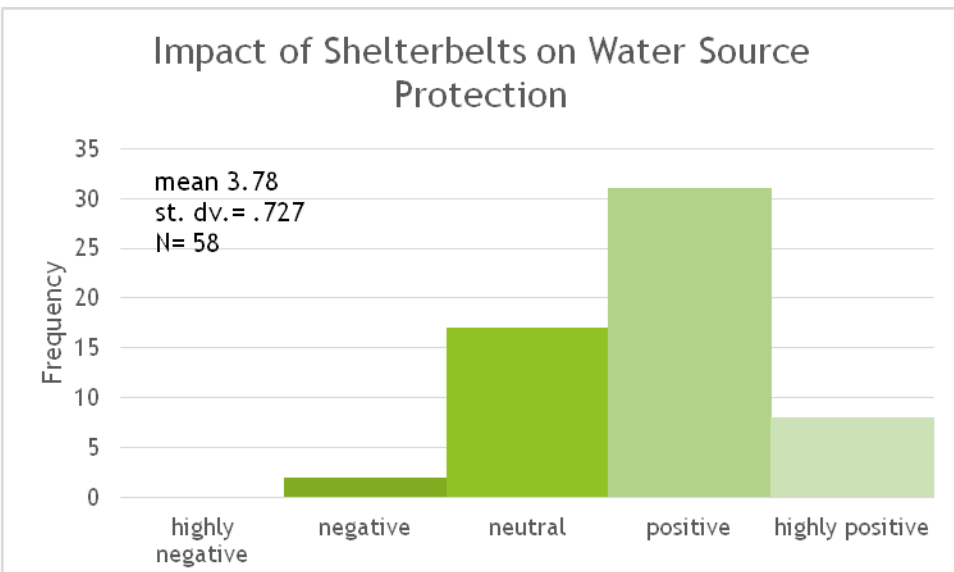

FIGURE B.I.30- IMPACT OF SHELTERBELTS ON WATER SOURCE PROTECTION AS INDICATED BY SURVEY PARTICIPANTS

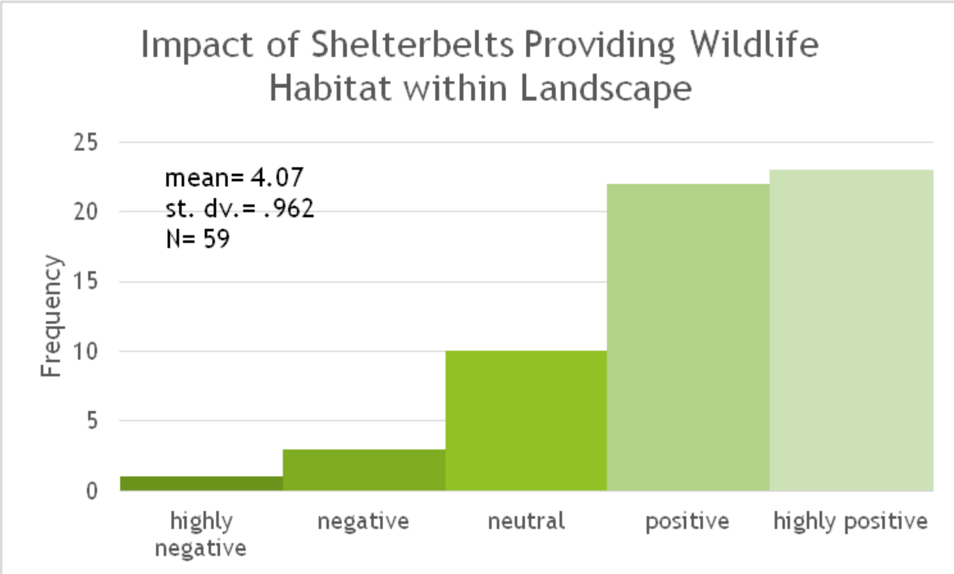

FIGURE B.I.31- IMPACT OF SHELTERBELTS IN PROVIDING WILDLIFE HABITAT WITHIN THEY LANDSCAPE AS INDICATED BY SURVEY PARTICIPANTS

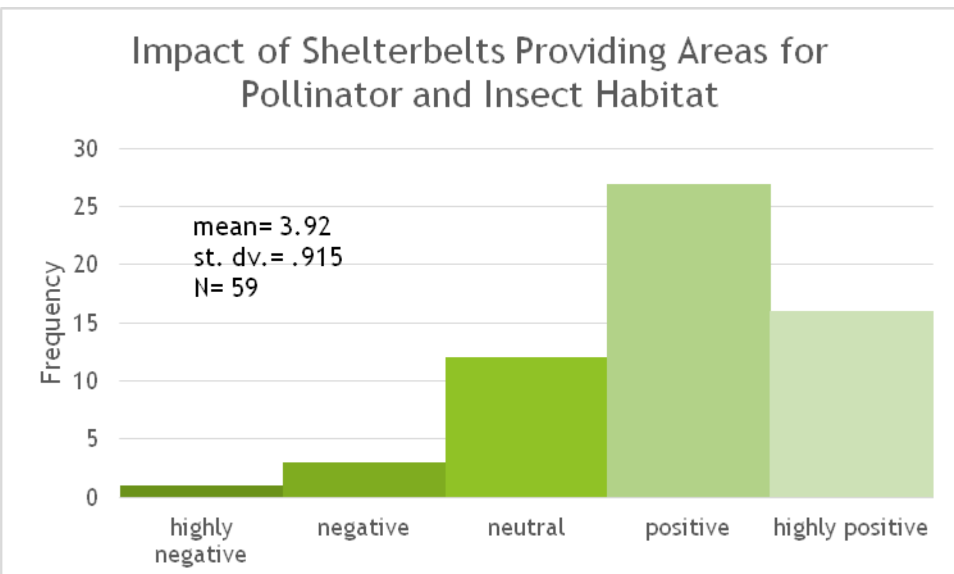

FIGURE B.I.32- IMPACT OF SHELTERBELTS IN PROVIDING AREAS FOR POLLINATORS (I.E., BEE) HABITAT AS INDICATED BY SURVEY PARTICIPANTS

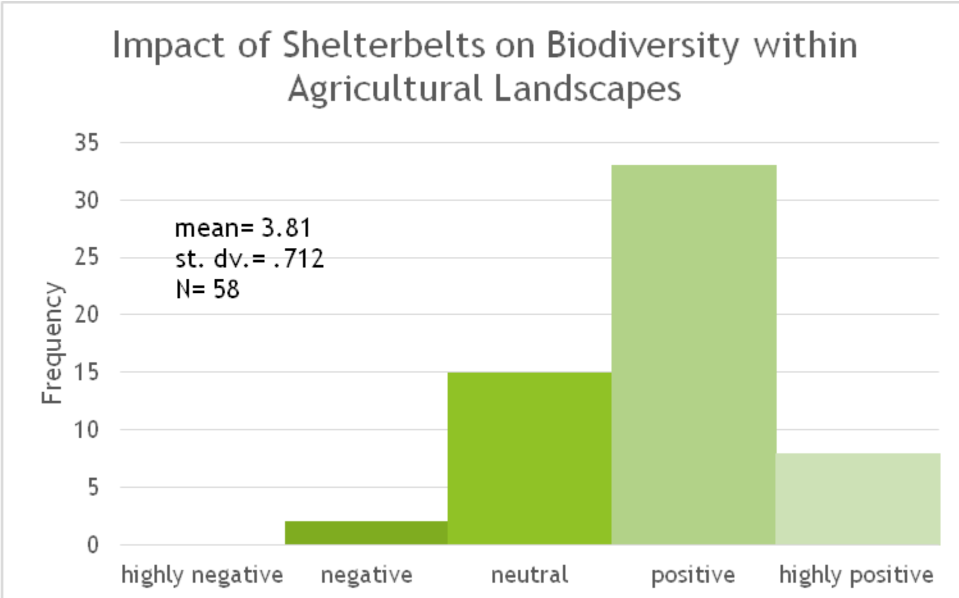

FIGURE B.I. 33- IMPACT OF SHELTERBELTS ON BIODIVERSITY WITHIN AGRICULTURAL LANDSCAPES AS INDICATED BY SURVEY PARTICIPANTS

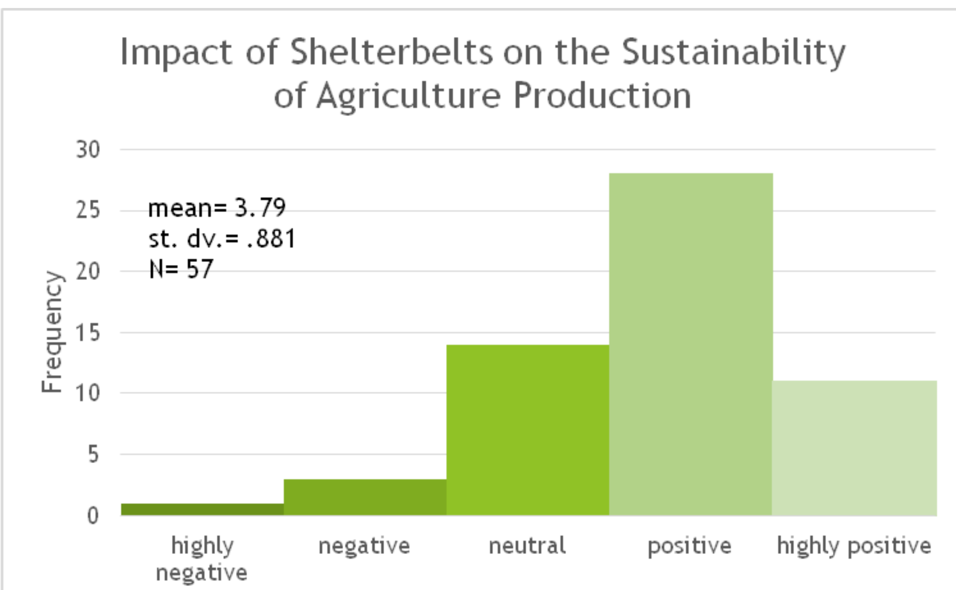

FIGURE B.I.34- IMPACT OF SHELTERBELTS ON THE SUSTAINABILITY OF AGRICULTURAL PRODUCTION AS INDICATED BY SURVEY PARTICIPANTS

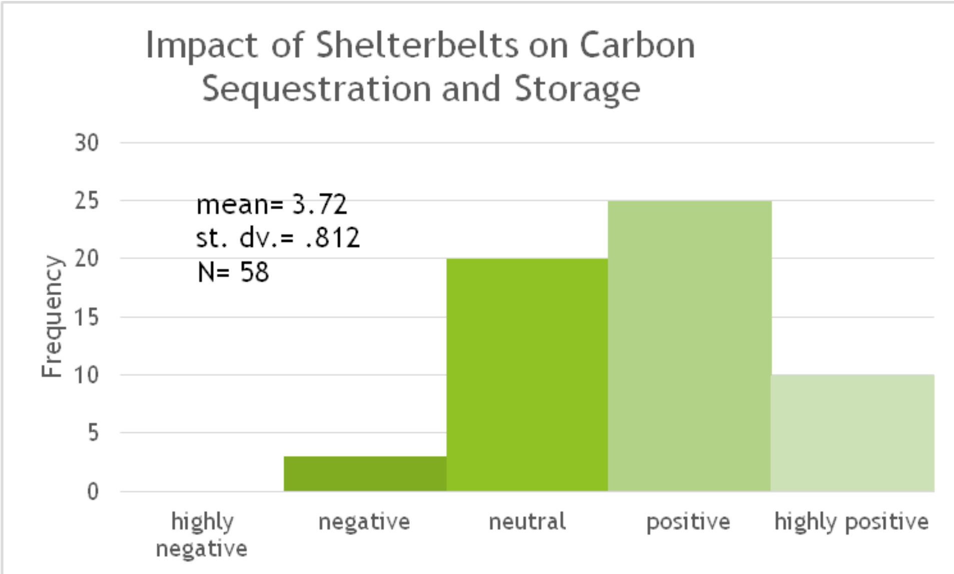

FIGURE B.I. 35- IMPACT OF SHELTERBELTS ON CARBON SEQUESTRATION AND STORAGE AS INDICATED BY SURVEY PARTICIPANTS

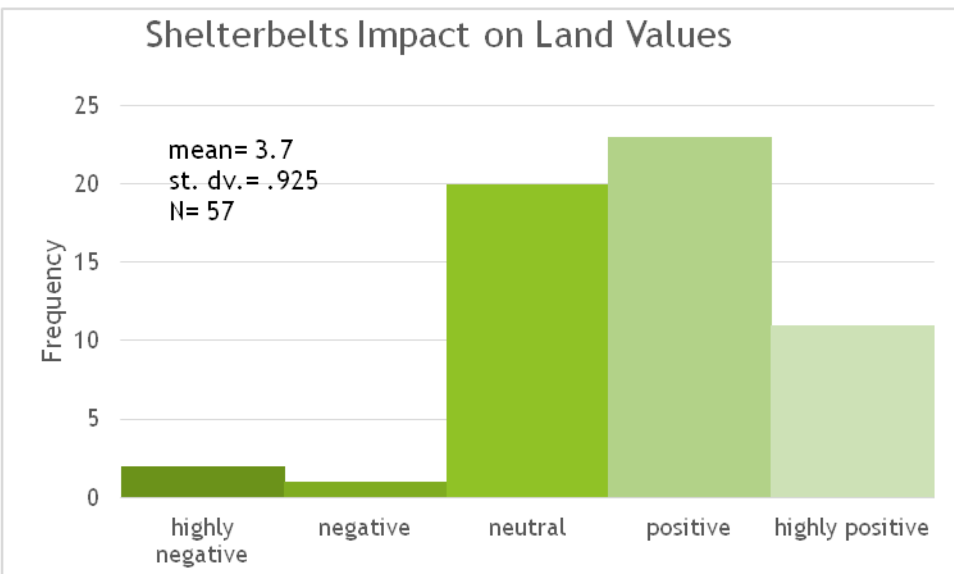

FIGURE B.I.36- SHELTERBELTS IMPACT ON LAND VALUES AS INDICATED BY SURVEY PARTICIPANTS

Part II

The information requested in this section is very important to our analysis of the questionnaire. We hope that asking for ranges will make it easier for you to answer this section. Please be assured that this information, like that in the rest of the questionnaire is strictly confidential.

12. What is your age?

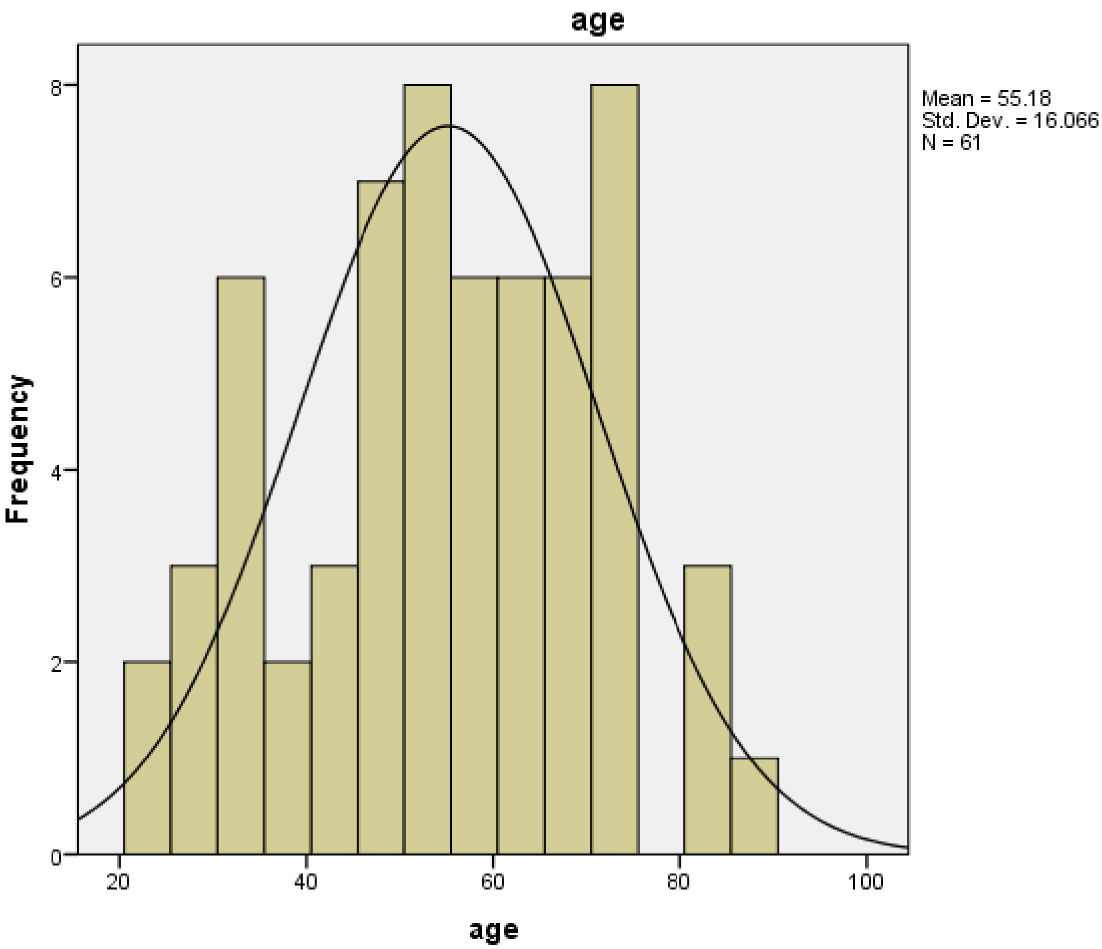

FIGURE B.II.1- DISTRIBUTION OF AGES OF PARTICIPANTS IN THE SURVEY SAMPLE

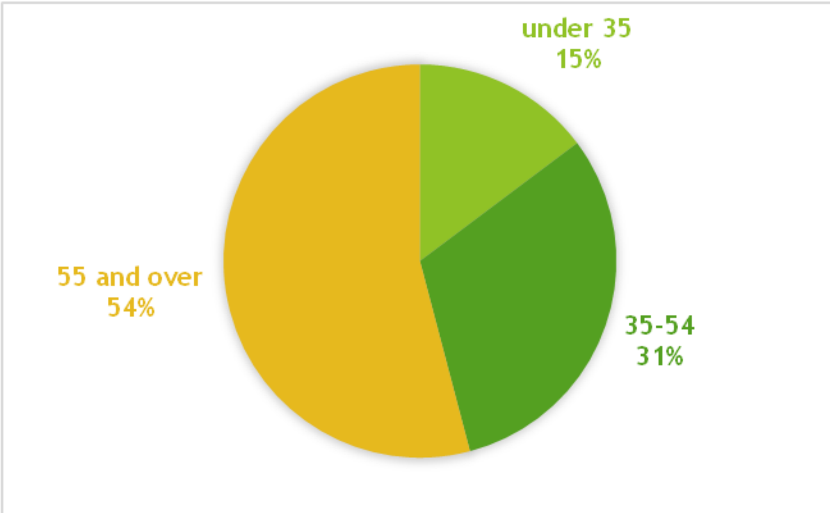

FIGURE B.II.2- AGE RANGE INDICATED BY SURVEY PARTICIPANTS

13. What is your gender?

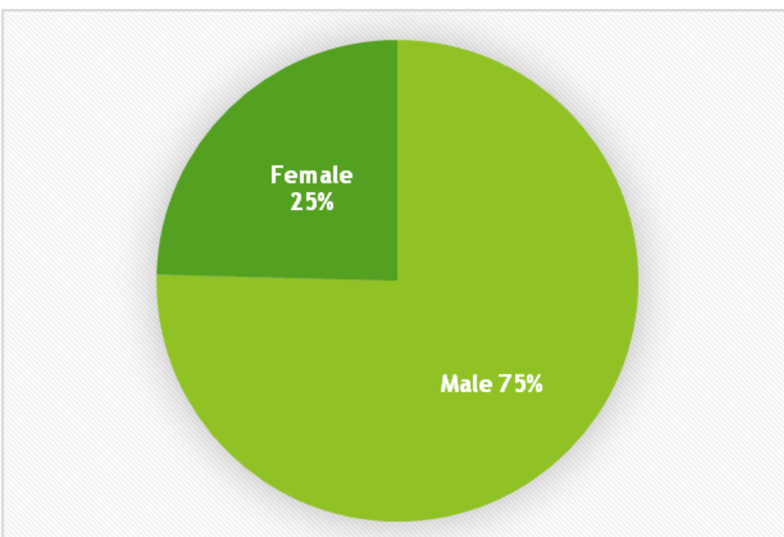

FIGURE B.II.3- GENDER INDICATED BY SURVEY PARTICIPANTS

14. How many years have you been farming, since the age of 18? ________ (years)

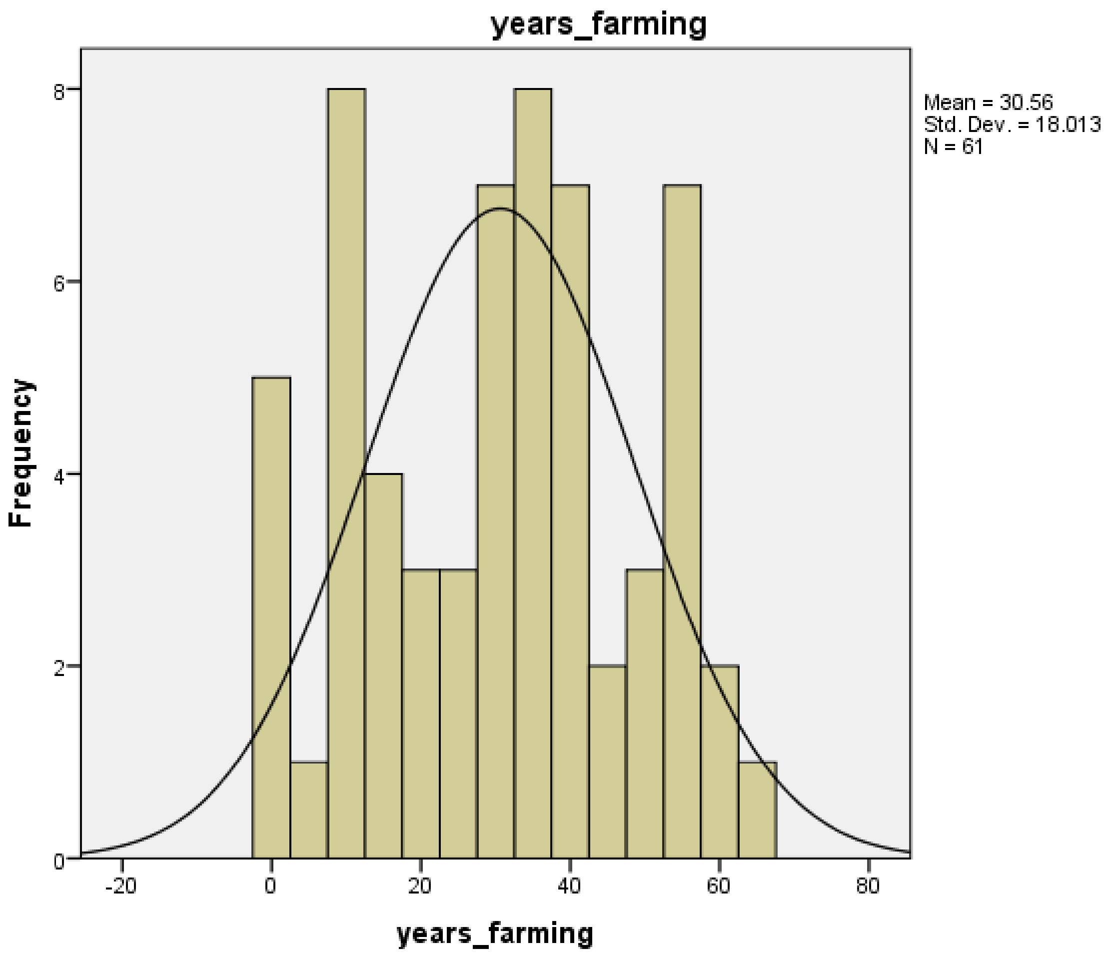

FIGURE B.II. 4- DISTRIBUTION OF NUMBER OF YEARS FARMING EXPERIENCE INDICATED BY SURVEY PARTICIPANTS

15. What is the highest level of education that you have completed?

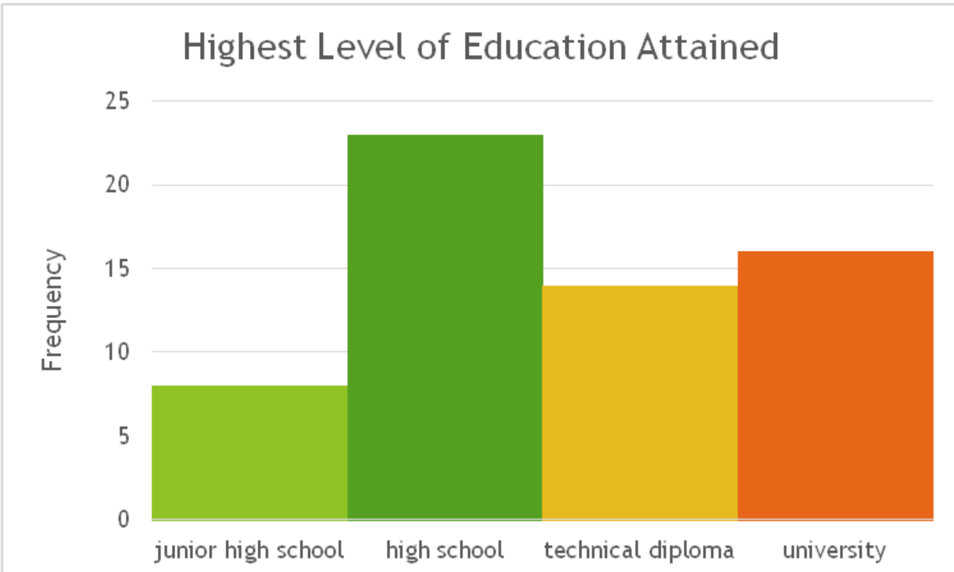

FIGURE B.II.5- LEVEL OF EDUCATION ACHIEVED AS INDICATED BY SURVEY PARTICIPANTS

17. What is the legal land description of your farm? ___________________________

Used for Map Figure 9, Soil Zone classification, ecozone, and ecoregion classification.

18. What was the gross farm sales last year? (Check range)

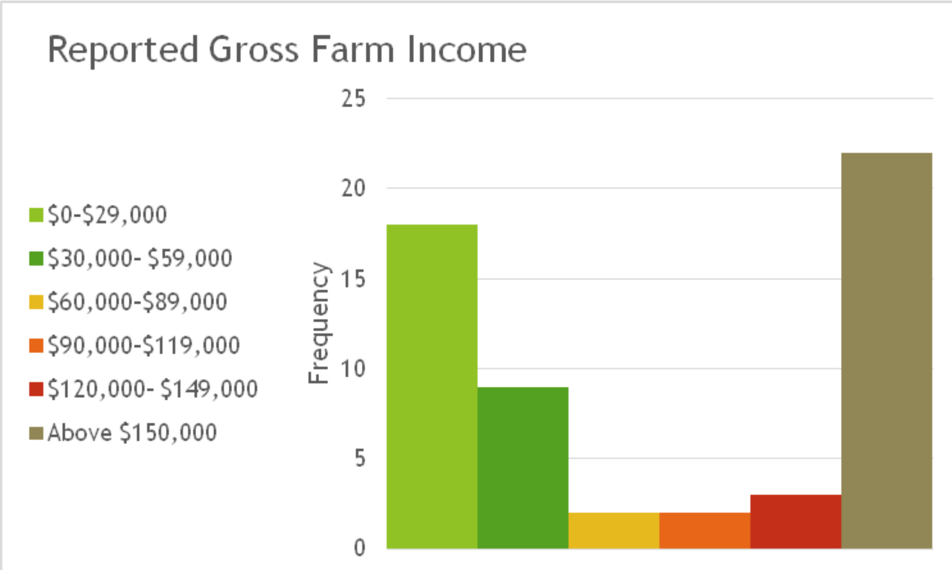

FIGURE B.II.6- GROSS INCOME LEVEL RANGE INDICATED BY SURVEY PARTICIPANTS

20. As a producer, do you think that the benefits associated with shelterbelts are greater than the costs?

		FREQUENCY	PERCENT	VALID PERCENT	CUMULATIVE PERCENT
VALID	yes	42	68.9	71.2	71.2
	no	8	13.1	13.6	84.7
	uncertain	9	14.8	15.3	100.0
	Total	59	96.7	100.0	
MISSING	System	2	3.3		
TOTAL		61	100.0		

Appendix C- Cost and Benefits Identified by Entire Sample

Appendix C the costs and benefits identified by the entire sample broken into those who have removed and those who have not removed shelterbelts into cost or benefits and market or non-market costs with the number of respondents commenting for each benefit or cost.

TABLE C.1- RESPONDENTS WHO INDICATED REMOVAL OF SHELTERBELTS WITH THEIR COMMENTS GROUPED INTO BENEFITS OR COSTS AND MARKET OR NON-MARKET CATEGORIES WITH NUMBER OF RESPONDENTS PER COMMENT

Factors related to benefit or cost	Market or Non Market	Number of Respondents commenting
Benefits		
Protection of my home	Non-market	8
Protection from the wind/the elements	Non-market	8
Protection from blowing snow	Non-market	5
Reducing soil erosion	Non-market	4
Wildlife in landscape	Non-market	4
Aesthetics/beauty	Non-market	3
Protection of outbuildings	Non-market	3
Reduction of dust blowing	Non-market	3
Birds	Non-market	3
Fire wood	Market	2
Uptake of excess moisture	Non-market	1
Water protection by trees nears streams or water bodies	Non-market	1
Wintering and calving sites for livestock	Non-market	1
Maintaining a natural state of the land	Non-market	1
Edible berries	Non-market	1
Improved moisture for pasture	Non-market	1
Privacy	Non-market	1
Reduced home heating costs	Market	1
Payments for carbon credits	Market	1
Value of established shelterbelts on land	Market	1
Tress around dugout for snow capture	Non-market	1
Costs		
Spraying weeds or insects in shelterbelts	Market	14
Manual labour for planting	Market	12
Tree death		9
Shelterbelts are a nuisance or hazard with large equipment	Market	8
Tree removal costs	Market	8
Labour for maintenance (i.e., weeding)	Market	6

Future costs of purchasing trees	Market	4
Snow capture creating problems with runoff or late spring melt delaying seeding	Market	4
Caraganas getting into natural bush, creating issues, and/or messy	Non-market	3
Shelterbelts encourage wildlife and they damage crops	market	2
Watering of trees	Market	2
Problems with leaves accumulating	Non-market	2
Salinity issues made worse with shelterbelts	Non-market	2
Shelterbelts make crops prone to lodging	Market	1
Habitat for harmful insects that damage crops in shelterbelts	Market	1
Decreases land values for crop producers	Market	1
Creates algae in dugouts	Non-market	1
Fencing off of shelterbelts from livestock	Market	1
Shelterbelts are inadequate in protection from extreme wind events	Non-market	1
Land that could be used for production is lost	Market	1
Concentration of pesticide drift on downward side		1
Increased production costs	Market	1
Increased time per field	Market	1
Roots damaging sewer and water lines near the house	Market	1
Moisture competition between shelterbelt and crops	market	1

TABLE C.2- BENEFITS OR COSTS (EITHER MARKET OR NON-MARKET) AS INDICATED BY THOSE WHO HAVE NOT REMOVED SHELTERBELTS WITH THE NUMBER OF RESPONDENTS INDICATING EACH COMMENT

Factors Related to Benefit or Cost	Market or Non-market	Number of Respondents commenting
Benefit		
Snow capture	Non-market	9
Variety/beauty in the landscape	Non-market	7
Protection from the wind	Non-market	7
Shelter for livestock	Non-market	6
Habitat for birds/birds	Non-market	5
Sentimental value of trees	Non-market	5
Eating/harvesting berries		5
Helpful around the yard (i.e., less snow plowing)		5
Reducing soil erosion/soil protection	Non-market	5
Improved property values	Market	4
Wildlife habitat	Non-market	4
Shelter	Non-market	4
Protection from snow	Non-market	4
Privacy	Non-market	4
Protection of crops from wind/elements	Non-market	3
Beneficial insects (i.e., bees)	Non-market	3
Carbon sequestration/climate change impacts	Non-market	3
Increased yields	Market	3
Essential part of organic production	Non-market	2
Ecological/environmental benefits	Non-market	2
Firewood for personal use		2
Reclaiming marginal land with planting trees	Non-market	2
Hunting in and around shelterbelts and trees	Non-market	2
Improved quality of life	Non-market	2
Marking the quarter lines/ edge of the property	Non-market	1
Opportunity to host outdoor events (i.e., wedding)	Non-market	1
Lumber to make buildings	Market	1
Firewood for commercial sale	Market	1
Trees slowing down water flow/runoff	Non-market	1
Harvesting of edible wild mushrooms	Non-market	1
Trapping of airborne weed seeds	Non-market	1
Valuable lesson/experience for children	Non-market	1
Good place for children to play	Non-market	1
Mowing and fertilizer benefits of a silvopasture set up	Non-market	1
Costs		
Manual labour for planting	Market	21
Maintenance	Market	16
Spraying for insects/weeds	Market	5
Harder for larger equipment to get around	Market	3

Purchased trees to get different species than available through the PFRA	Market	3
Deer/wildlife doing damage to crops/problem levels	Market	3
Neighbours/others taking out shelterbelts causing issues in the landscape (i.e., snow management)	Non-market	3
Tree death	Non-market	3
Competition for moisture with trees and crops	Market	3
Fencing off shelterbelts from livestock/livestock damaging trees	Market	2
Protection of livestock	Non-market	2
Snow captured in fence line by shelterbelt increase fence repair costs	Market	2
Replacing trees that have died	Market	2
Chronic hip issues in "digging" hip	Non-market	1
Difficulty getting labourers to plant and take care of trees	Market	1
Land values lower if you are selling to a larger farmer	Market	1
Some neighbours not happy with us keeping our shelterbelts on land adjacent to theirs	Non-market	1
Spacing is a challenge	Non-market	1
Time required for shelterbelts	Market	1
Professional tree moving services	Market	

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Appendix D Correlation of Likert Scale Ranking Questions Used to Construct Mind Map

Bivariate correlation analysis was conducted to determine the correlations between Likert-Scale ranking questions. This table includes variables with Pearson Correlations with significant results for the 99% confidence interval. With these types of questions, being on a discrete scale, the correlations serve only as an indicator of the relationship. These correlations were used to construct a mind-map for factors that correlations greater than 0.45 and were significant. Table D.1 shows these bivariate correlation coefficients estimated using SPSS.

Table D. 1- Bivariate Correlation Analysis for Likert Scale Ranking Questions

Factor		yields	irrigation efficiency	pesticide drift	land out of production	agcrop prices	soil erosion	snow capture moisture	reduced wind	micro-climate	overlap	dugout filling	livestock protection	improved feed use	odour control	shelter around home	outbuilding shelter	beauty	air quality	water protection	wildlife habitat	pollinators	biodiversity	sustain-ability	carbon sequestration	land values
yields	r	1	.445	.165	.173	.163	.304	.364	.419	.148	.111	-.067	.039	.241	.108	.019	-.074	-.118	.085	.321	.185	.184	.318	.283	.093	.360
	Pr.		.006	.225	.199	.238	.022	.005	.001	.272	.426	.675	.786	.092	.439	.890	.582	.377	.525	.015	.164	.168	.016	.035	.491	.006
	N	59	37	56	57	54	57	58	57	57	54	42	50	50	54	58	58	58	58	57	58	58	57	56	57	56
irrigation efficiency	r	.445	1	.454	.570	.261	.506	.353	.541	.273	.258	.227	.257	.288	.216	.093	.139	.004	.366	.526	.307	.160	.526	.586	.433	.226
	Pr.	.006		.004	.000	.124	.001	.030	.000	.103	.117	.255	.130	.084	.193	.580	.406	.982	.024	.001	.061	.337	.001	.000	.007	.186
	N	37	38	38	38	36	38	38	38	37	38	27	36	37	38	38	38	38	38	38	38	38	38	38	37	36
pesticide drift	r	.165	.454	1	.351	.033	.417	.359	.417	.225	.217	.498	.452	.296	.419	.069	.452	.248	.456	.604	.426	.504	.522	.648	.590	.21 7
	Pr.	.225	.004		.007	.813	.001	.006	.001	.099	.114	.001	.001	.039	.002	.609	.000	.063	.000	.000	.001	.000	.000	.000	.000	.111
	N	56	38	57	57	54	56	57	56	55	54	42	49	49	53	57	57	57	57	56	57	57	56	55	56	55
Land out of production	r	.173	.570	.351	1	.358	.381	.269	.375	.182	.527	.189	.317	.370	.127	-.105	-.055	-.070	.202	.272	.139	.057	.215	.305	.434	.088
	Pr.	.199	.000	.007		.008	.003	.041	.004	.180	.000	.226	.025	.008	.360	.433	.682	.604	.128	.041	.297	.672	.109	.022	.001	.519
	N	57	38	57	58	54	57	58	57	56	54	43	50	50	54	58	58	58	58	57	58	58	57	56	57	56
agcrop prices	r	.163	.261	.033	.358	1	.119	.287	.426	.031	.199	.050	-.094	.063	-.129	-.155	-.207	-.199	-.161	.025	-.032	-.134	.022	-.013	.113	-.084
	Pr.	.238	.124	.813	.008		.392	.034	.001	.822	.158	.756	.529	.671	.361	.258	.129	.145	.239	.860	.819	.330	.871	.927	.416	.551
	N	54	36	54	54	55	54	55	54	54	52	41	47	48	52	55	55	55	55	54	55	55	55	53	54	53

soil erosion	r	.304	.506	.417	.381	.119	1	.366	.522	.028	.302	.252	.122	.094	.132	.116	.175	0.00	.058	.387	.267	.216	.292	.480	.492	.089
	Pr.	.022	.001	.001	.003	.392		.005	.000	.840	.025	.108	.395	.511	.342	.384	.188	1.00	.664	.003	.042	.103	.028	.000	.000	.516
	N	57	38	56	57	54	58	58	58	56	55	42	51	51	54	58	58	58	58	57	58	58	57	57	57	56
Snow	r	.364	.353	.359	.269	.287	.366	1	.442	.016	.170	.298	.146	.074	.102	-.058	.035	-.079	.074	.269	.303	.207	.367	.302	.330	.266
	Pr.	.005	.030	.006	.041	.034	.005		.001	.903	.214	.052	.307	.607	.460	.661	.795	.550	.575	.041	.020	.115	.005	.022	.011	.046
	N	58	38	57	58	55	58	59	58	57	55	43	51	51	55	59	59	59	59	58	59	59	58	57	58	57
reduced wind damage	r	.419	.541	.417	.375	.426	.522	.442	1	.032	.295	.412	.232	.188	.308	-.001	.172	-.086	.132	.466	.319	.325	.491	.512	.408	.146
	Pr.	.001	.000	.001	.004	.001	.000	.001		.818	.029	.007	.102	.185	.024	.991	.196	.523	.323	.000	.015	.013	.000	.000	.002	.282
	N	57	38	56	57	54	58	58	58	56	55	42	51	51	54	58	58	58	58	57	58	58	57	57	57	56
microclimate	r	.148	.273	.225	.182	.031	.028	.016	.032	1	.006	.308	.364	.435	.431	.187	.196	.116	.439	.386	.285	.174	.250	.113	.043	.310
	Pr.	.272	.103	.099	.180	.822	.840	.903	.818		.965	.050	.010	.002	.001	.165	.145	.391	.001	.003	.031	.195	.060	.413	.751	.021
	N	57	37	55	56	54	56	57	56	57	53	41	49	50	54	57	57	57	57	56	57	57	57	55	56	55
overlap	r	.111	.258	.217	.527	.199	.302	.170	.295	.006	1	.144	.056	.106	.002	-.022	-.093	.080	.154	.072	.151	.154	.312	.155	.261	.025
	Pr.	.426	.117	.114	.000	.158	.025	.214	.029	.965		.375	.705	.472	.990	.873	.500	.561	.261	.606	.270	.260	.022	.264	.057	.859
	N	54	38	54	54	52	55	55	55	53	55	40	48	48	52	55	55	55	55	54	55	55	54	54	54	53
dugout filling	r	-.067	.227	.498	.189	.050	.252	.298	.412	.308	.144	1	.305	.307	.507	-.141	.093	.116	.263	.485	.407	.306	.378	.337	.480	.207
	Pr.	.675	.255	.001	.226	.756	.108	.052	.007	.050	.375		.067	.073	.001	.368	.552	.461	.089	.001	.007	.046	.014	.031	.001	.184
	N	42	27	42	43	41	42	43	42	41	40	43	37	35	40	43	43	43	43	42	43	43	42	41	43	43
livestock protection	r	.039	.257	.452	.317	-.094	.122	.146	.232	.364	.056	.305	1	.737	.453	-.051	.100	.171	.308	.361	.387	.145	.250	.361	.327	.017
	Pr.	.786	.130	.001	.025	.529	.395	.307	.102	.010	.705	.067		.000	.001	.720	.485	.229	.028	.010	.005	.312	.080	.009	.021	.908
	N	50	36	49	50	47	51	51	51	49	48	37	51	49	48	51	51	51	51	50	51	51	50	51	50	49
improved feed use	r	.241	.288	.296	.370	.063	.094	.074	.188	.435	.106	.307	.737	1	.541	-.156	.090	.011	.316	.353	.260	.195	.229	.132	.207	.120
	Pr.	.092	.084	.039	.008	.671	.511	.607	.185	.002	.472	.073	.000		.000	.273	.528	.940	.024	.012	.065	.171	.106	.355	.150	.410

	N	50	37	49	50	48	51	51	51	50	48	35	49	51	49	51	51	51	51	50	51	51	51	51	50	49
odor	r	.108	.216	.419	.127	-.129	.132	.102	.308	.431	.002	.507	.453	.541	1	.041	.340	.154	.461	.417	.365	.426	.381	.273	.305	.289
	Pr.	.439	.193	.002	.360	.361	.342	.460	.024	.001	.990	.001	.001	.000		.769	.011	.260	.000	.002	.006	.001	.004	.048	.025	.036
	N	54	38	53	54	52	54	55	54	54	52	40	48	49	55	55	55	55	55	54	55	55	55	53	54	53
shelter around home	r	.019	.093	.069	-.105	-.155	.116	-.058	-.001	.187	-.022	-.141	-.051	-.156	.041	1	.424	.237	.050	-.070	.152	.195	.249	.188	.140	-.056
	Pr.	.890	.580	.609	.433	.258	.384	.661	.991	.165	.873	.368	.720	.273	.769		.001	.071	.705	.604	.249	.139	.059	.162	.293	.677
	N	58	38	57	58	55	58	59	58	57	55	43	51	51	55	59	59	59	59	58	59	59	58	57	58	57
building shelter	r	-.074	.139	.452	-.055	-.207	.175	.035	.172	.196	-.093	.093	.100	.090	.340	.424	1	.368	.378	.360	.346	.548	.419	.351	.183	.081
	Pr.	.582	.406	.000	.682	.129	.188	.795	.196	.145	.500	.552	.485	.528	.011	.001		.004	.003	.005	.007	.000	.001	.007	.169	.550
	N	58	38	57	58	55	58	59	58	57	55	43	51	51	55	59	59	59	59	58	59	59	58	57	58	57
beautification	r	-.118	.004	.248	-.070	-.199	0.00	-.079	-.086	.116	.080	.116	.171	.011	.154	.237	.368	1	.312	.128	.173	.278	.127	.194	.245	.234
	Pr.	.377	.982	.063	.604	.145	1.00	.550	.523	.391	.561	.461	.229	.940	.260	.071	.004		.016	.337	.189	.033	.344	.147	.064	.080
	N	58	38	57	58	55	58	59	58	57	55	43	51	51	55	59	59	59	59	58	59	59	58	57	58	57
air quality	r	.085	.366	.456	.202	-.161	.058	.074	.132	.439	.154	.263	.308	.316	.461	.050	.378	.312	1	.516	.390	.395	.394	.253	.215	.443
	Pr.	.525	.024	.000	.128	.239	.664	.575	.323	.001	.261	.089	.028	.024	.000	.705	.003	.016		.000	.002	.002	.002	.058	.105	.001
	N	58	38	57	58	55	58	59	58	57	55	43	51	51	55	59	59	59	59	58	59	59	58	57	58	57
water protection	r	.321	.526	.604	.272	.025	.387	.269	.466	.386	.072	.485	.361	.353	.417	-.070	.360	.128	.516	1	.520	.521	.572	.604	.460	.276
	Pr.	.015	.001	.000	.041	.860	.003	.041	.000	.003	.606	.001	.010	.012	.002	.604	.005	.337	.000		.000	.000	.000	.000	.000	.039
	N	57	38	56	57	54	57	58	57	56	54	42	50	50	54	58	58	58	58	58	58	58	57	56	57	56
wildlife habitat	r	.185	.307	.426	.139	-.032	.267	.303	.319	.285	.151	.407	.387	.260	.365	.152	.346	.173	.390	.520	1	.476	.589	.369	.391	.225
	Pr.	.164	.061	.001	.297	.819	.042	.020	.015	.031	.270	.007	.005	.065	.006	.249	.007	.189	.002	.000		.000	.000	.005	.002	.093
	N	58	38	57	58	55	58	59	58	57	55	43	51	51	55	59	59	59	59	58	59	59	58	57	58	57

pollinators	r	.184	.160	.504	.057	-.134	.216	.207	.325	.174	.154	.306	.145	.195	.426	.195	.548	.278	.395	.521	.476	1	.599	.545	.296	.261
	Pr.	.168	.337	.000	.672	.330	.103	.115	.013	.195	.260	.046	.312	.171	.001	.139	.000	.033	.002	.000	.000		.000	.000	.024	.050
	N	58	38	57	58	55	58	59	58	57	55	43	51	51	55	59	59	59	59	58	59	59	58	57	58	57
biodiversity	r	.318	.526	.522	.215	.022	.292	.367	.491	.250	.312	.378	.250	.229	.381	.249	.419	.127	.394	.572	.589	.599	1	.691	.351	.250
	Pr.	.016	.001	.000	.109	.871	.028	.005	.000	.060	.022	.014	.080	.106	.004	.059	.001	.344	.002	.000	.000	.000		.000	.007	.063
	N	57	38	56	57	55	57	58	57	57	54	42	50	51	55	58	58	58	58	57	58	58	58	56	57	56
sustainability	r	.283	.586	.648	.305	-.013	.480	.302	.512	.113	.155	.337	.361	.132	.273	.188	.351	.194	.253	.604	.369	.545	.691	1	.605	.138
	Pr.	.035	.000	.000	.022	.927	.000	.022	.000	.413	.264	.031	.009	.355	.048	.162	.007	.147	.058	.000	.005	.000	.000		.000	.316
	N	56	38	55	56	53	57	57	57	55	54	41	51	51	53	57	57	57	57	56	57	57	56	57	56	55
carbon sequestration	r	.093	.433	.590	.434	.113	.492	.330	.408	.043	.261	.480	.327	.207	.305	.140	.183	.245	.215	.460	.391	.296	.351	.605	1	.123
	Pr.	.491	.007	.000	.001	.416	.000	.011	.002	.751	.057	.001	.021	.150	.025	.293	.169	.064	.105	.000	.002	.024	.007	.000		.361
	N	57	37	56	57	54	57	58	57	56	54	43	50	50	54	58	58	58	58	57	58	58	57	56	58	57
land values	r	.360	.226	.217	.088	-.084	.089	.266	.146	.310	.025	.207	.017	.120	.289	-.056	.081	.234	.443	.276	.225	.261	.250	.138	.123	1
	Pr.	.006	.186	.111	.519	.551	.516	.046	.282	.021	.859	.184	.908	.410	.036	.677	.550	.080	.001	.039	.093	.050	.063	.316	.361	
	N	56	36	55	56	53	56	57	56	55	53	43	49	49	53	57	57	57	57	56	57	57	56	55	57	57

Appendix E Cost and Benefits Identified and Group by Sup-Groups

This Appendix covers the open question comments made by producers. The comments have been divided into two sub groups: 1) those who have removed and not removed shelterbelts and 2) responses by Soil Zone. These sub-groups are the two sub-groups that were analyzed in the Section 6.3- Sub Sample Analysis.

I. Removal and Non-Removal Sub-Group

This section includes the results from the open questions related to the costs and benefits of shelterbelts. For this section the open question responses are broken into those who have and who have not removed shelterbelts. Table D.I.1 contains the results of the open question comments for those who have and who have not removed shelterbelts.

TABLE E.I 1-COMMENTS FROM THE SURVEY PARTICIPANTS IN THE OPEN QUESTIONS GROUPED BY THOSE WHO HAVE REMOVED AND THOSE WHO HAVE NOT REMOVED SHELTERBELTS AND THEN FURTHER BROKEN INTO MARKET OR NON-MARKET COSTS OR BENEFITS

Shelterbelt Removal			
Factors Related to Costs		**Factors Related to Benefits**	
Market	**Non-Market**	**Market**	**Non-Market**
- Spraying for insects in shelterbelt - Manual labour for planting - Spraying weeds or insects in shelterbelts - Shelterbelts are in the way for large equipment - Tree removal costs - Time requirement for planting/maintaining - Labour for maintenance (i.e., weeding) - Future costs of purchasing trees - Snow capture creating problems with runoff or late spring melt delaying seeding - Shelterbelts encourage	- Tree death - Caraganas getting into natural bush, creating issues, and/or messy - Problems with leaves accumulating - Salinity issues made worse with shelterbelts	- Fire wood	- Protection of my home - Protection from the wind/the elements - Protection from - blowing snow -Reducing soil erosion -Wildlife in landscape - Aesthetics/beauty - Protection of outbuildings - Reduction of dust blowing - Birds

wildlife and they damage crops - Watering of trees			
No Shelterbelt Removal			
-Manual labour for planting - Maintenance - Spraying for insects/weeds - Harder for larger equipment to get around - Purchased trees to get different species than available through the PFRA - Fencing off shelterbelts from livestock/livestock damaging trees - Snow captured in fence line by shelterbelt increase fence repair costs - Replacing trees that have died	-Deer/wildlife doing damage to crops/problem levels - Neighbours/others taking out shelterbelts causing issues in the landscape (i.e., snow management) - Tree death - Competition for moisture with trees and crops - protection of livestock	- less snow plowing around the yard/on road - improved property values -increased crop yields - firewood for commercial sale - firewood for personal use	-Snow capture - Variety/beauty in the landscape - Protection from the wind - Shelter for livestock - Habitat for birds/bees - Sentimental value of trees - Eating/harvesting berries (personal use) - Reducing soil erosion/soil protection Wildlife habitat - Shelter - Protection from snow - Privacy - Protection of crops from wind/elements - Beneficial insects (i.e., bees) - Carbon sequestration/climate change impacts - Essential part of organic production - Ecological/environmental benefits - Reclaiming marginal land with planting trees - Hunting in and around shelterbelts and trees - Improved quality of life

II. Soil Zone Sub-Group

This section includes the results from the open questions related to the costs and benefits of shelterbelts. For this section the open question responses are broken down by the agricultural Soil Zone of Saskatchewan that each participant's farmyard home is located in. Table E.II.1 contains the results of the open question comments broken down by Soil Zone.

TABLE E.II 1- OPEN QUESTION RESPONSES FOR COSTS AND BENEFITS OF SHELTERBELTS BROKEN DOWN BY SOIL ZONE AND MARKET OR NON-MARKET NATURE OF THE BENEFIT OR COST

Brown Soil Zone			
Reasons Related to Costs		**Reasons Related to Benefits**	
Market Based	*Non-Market Based*	*Market Based*	*Non-Market Based*
- Fencing cost to reduce livestock damage -Fence repair from snow accumulation in fence line - Labour required for planting -Removal of shelterbelts - Tree death requiring replacement/renovation - Hazard/nuisance with large equipment - Snow pile up can delay seeding - Loss of PFRA will mean less trees/ requirement to purchase trees - Losses to crops from wildlife (less trees in landscape mean wildlife reach problem levels where there are trees) -Maintenance -Planting	- Pests damaging trees -Competition for moisture - Tree death messy/unsightly	- Ability to get free trees - R.M. tree planter reduced labour cost - Improved yields - Carbon payments - Allow for agricultural production on lighter soils - Minimal maintenance required once established - Minimal costs that are absorbed as a part of farming	-Shelter in the yard -Shelter/protection from the wind -Protection from snow/storms -Shelter for livestock -Wildlife habitat -Wildlife viewing -Bird habitat - Encourage beneficial insects - Indian Head/shelterbelts an important part of the prairies - Personal enjoyment/ increased quality of life - Trapping of airborne weed seeds in tree line - Protection of light soil/ reduction of soil erosion - Snow capture for moisture in fields - Good for the climate/environment -Beauty/ variety in the landscape

Dark Brown Soil Zone			
Reasons Related to Costs		Reasons Related to Benefits	
Market Based	*Non-Market Based*	*Market Based*	*Non-Market Based*
-Maintenance (annual) - Spraying for pests - Planting - Removal of trees - Tree replacement/ replanting - Irrigation - Bird/wildlife damage to crops and gardens - Make crops more prone to lodging - Personal/hired labour - Lower land values for crop production land with shelterbelts - Purchasing trees from greenhouse/ other sources -Increased costs of production - Delay seeding because of snow - Detrimental effects on Solonetzic soils -Damage to infrastructure (i.e., sewer line) - Hazard/nuisance for large equipment - Moisture competition	-Long term consequences associated with Indian Head closure - Concentration of pesticide on downwind side -Algae in dugouts - Tree death - Current location of shelterbelts not suitable for today's production - Weed issues - Chronic hip pain from planting - Pesticides harm bees	-Value of established shelterbelts - Free trees from PFRA - R.M. tree planter reduced labour/costs - No removal/renovation costs - Increase land value for acreages -Minimal costs that are absorbed as a part of farming - No maintenance -Protection for orchard for fruit production	-Protection from wind - Beauty and quality of life associated with trees in landscape/yard - Edible berries from trees - Reduced dust blowing off roads into yard - Bird habitat - Wildlife habitat - Privacy - Ability to transplant seedlings from understory to other areas - Snow capture for moisture beneficial in dry years - Increased predators for agriculturally harmful insects (i.e., birds) - Protection from blowing snow -Sentimental value of trees - Ecological benefits - Valuable life lessons for children about hard work - Habitat for pollinators - Protection/shelter for livestock - Reduced snow plowing

Black Soil Zone			
Reasons Related to Costs		**Reasons Related to Benefits**	
Market Based	*Non-Market Based*	*Market Based*	*Non-Market Based*
-Labour for planting -Weed control - Maintenance (initial and annual) - Wildlife damaging crops/ reducing yields - Removal of trees on crop land - Fencing to keep cows out - Removal of dead trees - Snow capture delaying seeding - Cost to purchase trees - Removal of caragana which were spreading to natural forest areas - Watering trees -Overlap/going around shelterbelts in field/near roads/fences -Hazard/nuisance for large equipment - Fertilizer - Use of agricultural land for trees - Moisture competition between trees and garden/crops	- Tree disease - Taking care of tree seedlings until established - Tree death - Areal herbicide/pesticide application damages non-target species (i.e., trees) - Poor location selection increases costs/inconvenience - Future generations less likely to plant without program like PFRA - Wildlife damage to shelterbelts causing increased costs	- Increased land value - Opportunity to host events (i.e., weddings) - Free trees - Value of established trees -Fire wood - Increased hay yields on shelterbelt fields - R.M. tree planter reduced labour/costs -Increased crop yields (some years) - Necessity for organic production - Government, industry, NGO incentives reduce costs - Rent from land with established shelterbelts - Crop protection - Reduction of labour for snow removal	- Good land management/stewardship practice - Protection for farm infrastructure from wind/snow - Improved quality of life/enjoyment - Beauty/ diversity in landscape - Livestock shelter (i.e., winter and calving) - Shade for livestock - Minimal/no costs - Edible berries - Protection/shelter from blowing snow - Opportunity for natural reforestation/ regeneration of seedlings - Soil protection (i.e., reduced erosion) - Protection from the wind/reduced wind speed - Wildlife habitat - Reduced blowing dust - Natural shelterbelts have no maintenance/labour - Bird habitat/ increased bird populations (i.e., Grouse) - Soil protection - Trap snow (added moisture and less blowing) - Does not feel like work to maintain/have shelterbelts - On farm use for flax shives (placed at base of trees to retain moisture) - Shelter for farmyard from wind and snow

Dark Gray/Gray Soil Zone			
Reasons Related to Costs		**Reasons Related to Benefits**	
Market Based	*Non-Market Based*	*Market Based*	*Non-Market Based*
-Personal/hired labour - Maintenance (annual) - Planting - Purchasing of trees -Removal of natural bush in region means more wildlife in shelterbelts that pose a threat to crop production - Can be in the way of equipment depending on location -Delays in seeding with increased snow capture - Large producers may not see shelterbelts as a value added (lower resale value to them) -Removal of dead trees - Spraying for pests (weeds/disease) -Moisture competition between crops and trees - Changes in farming technology have increased costs and reduced benefits - Fencing costs	- Tree death - Sensitivity to pesticide drift - Poor species selection can cause issues - Less R.M. support now than there used to be - Increased water runoff when captured snow melts quickly - Poor species selection can cause issues (i.e., messy maples, caraganas getting into natural bush) - Dead trees can pose a fire hazard/fuel loading - Poor site selection necessitates removal	- Increased land values - Little/no maintenance once established/planted - Yield increases for organic production/ essential for organic production - Wood for lumber -Wood for firewood -Natural shelterbelts have no maintenance -Value of established shelterbelts when purchasing land - Free trees from PFRA -Reduced snow removal/plowing costs - Reduced heating and cooling costs for home - Allowance/payment for carbon credits	- Protection/shelter from the wind -Protection from blowing snow - Reduced soil erosion -snow management/capture for moisture - Moisture retention in riparian areas - Marking quarter lines in field - Use for saw dust, from other operation on farm, to retain moisture - Hunting in and around shelterbelts -Edible berries - Shelter for livestock - Reclamation of marginal lands with trees - Natural reforestation - Environmental protection -Slows water runoff in spring - Wild mushrooms - Improved quality of life/ well being -Privacy -Carbon sequestration - Reduction of wind erosion of soil - Maintains a more natural state of the land with farming as one part not whole -Habitat for pollinators/ bee population needs trees -Wildlife habitat - Beauty in landscapes/yard - Improved moisture conditions in pastures - Protection from blowing dust - Habitat for birds -Uptake of excess moisture in wet years

Appendix F-AGGP site selection protocol – a short description

Written by Beyhan Amichev and shared with his permission for the purpose of this thesis:

An integral part of the field data collection in the AGGP project was to know which species and their approximate age that were available for sampling at a given township. This information was obtained from a shelterbelt tree orders and distribution database for the Prairie shelterbelt program (PSP) which was described in detail in Amichev et al. (2014). In short, the PSP shelterbelt tree orders from 1925 to 2009 were analyzed, and the intended tree planting locations of all shelterbelt tree orders were mapped. Each record in the PSP database contained the name and quantity of the shelterbelt species ordered, the year when the order was made, and a legal land description which was converted to latitude and longitude coordinates for mapping purposes.

All shelterbelt tree orders were mapped and then overlaid with a cluster map of all agricultural ecodistricts in Saskatchewan (Amichev et al., 2014). Within each cluster, the total number of shelterbelt trees was summarized by species. One cluster was identified, among all 31 clusters in agricultural Saskatchewan, which had the highest cumulative number of shelterbelt trees for a specific species that were sent from PSP; this cluster was designated as the parameterization cluster. This cluster was used to randomly locate sites for field sampling of shelterbelts. For each species, one field site was located within each of ten age classes to assure complete coverage of the age range of planted shelterbelts.

Shelterbelt field data collection for the AGGP project was designed to gather tree data at the shelterbelt level while sampling many sites across a very large extent of land at the provincial level. This site selection design, developed and implemented by the research associate involved in the AGGP project (Dr. Beyhan Amichev, 2013, personal communication) was adopted for the analyses in my thesis. In short, a unique study site selection approach was developed based on an existing randomized branch sampling (RBS) procedure by Valentine et al. (1984). The RBS procedure was modified to fit the needs of the AGGP project and was performed in three iterations for each study site (Dr. Beyhan Amichev, 2013, personal communication). In the first iteration of the RBS procedure, one ecodistrict of many was randomly selected within the parameterization cluster. In the second iteration of the RBS procedure, within the spatial extent of the randomly selected ecodistrict, one soil polygon (SLC, 2010) of many was selected at random. In the third iteration of the RBS procedure, within the spatial extent of the randomly selected soil polygon, one township location to which shelterbelt trees were sent from PSP was selected at random. In summary, by sampling shelterbelts at randomly selected township locations within randomly selected soil polygons within randomly selected ecodistricts within the parameterization cluster, all bias in the collected shelterbelt field data was minimized (Dr. Beyhan Amichev, 2013, personal communication).