Costs and benefits of shelterbelts: A review of producers' perceptions and mind map analyses for Saskatchewan, Canada

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Abstract The role of shelterbelts within prairie agriculture is changing. In the past, shelterbelts have been promoted and adopted to reduce soil erosion and to protect farmsteads and livestock from harsh prairie climates. Production techniques used today have been changed from when shelterbelts were first introduced as a management practice to reduce erosion. Advances in production technology accompanied with increase in farm size and changes to policy have all contributed to a shift in how shelterbelts are considered within management plans. The objective of this research is to identify the private costs and benefits from adoption and retention of shelterbelts. In the summer of 2013, a survey was conducted of producers and land owners chiefly from Saskatchewan, Canada. It was found that many of the benefits of shelterbelts can be classified as non-economic and therefor are more difficult for producers and land owners to recognize or include within their operations management decisions. Conversely the costs to producers were easily identified and heavily influenced management decisions. As greenhouse gas management and policy become more of a focus, 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 above- and belowground parts of planted shelterbelt trees or shrubs. However, most producers do not recognize such benefits within their management decisions as they are not currently compensated for the benefits that they provide to society.

Keywords: **s**helterbelts. Saskatchewan, costs, benefits, perception.

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Introduction

Shelterbelts are rows of planted or naturally regenerated trees that are used chiefly to reduce wind speed and wind impact on the prairies. They are also known as living hedges, windbreaks, living fences, or hedgerows. Traditionally they have been used to reduce soil erosion from wind but as production technologies have changed (i.e., adoption of zero till, reduced summerfallowing), the emphasis on these benefits has diminished (Kulshreshtha et al., 2010). Private land owners bear the costs associated with shelterbelts on their lands, which have increased over time. For example, the discontinuation of the Prairie Farm Rehabilitation Administration free tree distribution program now requires farmers to purchase trees for shelterbelts (Kulshreshtha and Rempel, 2014). Now, zero tillage and reduced summerfallowing practices are often viewed as a replacement erosion mitigation technique (Casement and Timmermans, 2007), making shelterbelts might be considered by some producers as redundant. Furthermore, maneuvering around shelterbelts with large equipment imposes reduced efficiency of seeding, spraying, and harvest operations (Kulshreshtha and Rempel, 2014). Understanding the scope of private and social costs and benefits of adopting / retaining shelterbelts by prairie producers is advantageous in understanding current management practices as well as useful in designing climate change mitigation policy related to shelterbelts and their management.

This research focuses on the producers' perception of costs and benefits of adoption and retention of shelterbelts, including the role shelterbelts play in providing environmental goods and services (i.e., greenhouse gas mitigation, habitat provision).This research builds on previous research done by Kulshreshtha and Knopf (2003) that looked at the benefits from the PFRA and Agricultural Canada's shelterbelt program. This study looked at societal benefits from the program and had conclusions related to the importance of shelterbelts in GHG mitigation. In addition to this research, classification and examination of the economic benefits and costs from shelterbelts has been carried out by Brandle et al. (1992a). This research was an excellent overview, however, production techniques have advanced since this time and the aim of this research was aiming to classify costs and benefits under current agricultural practices (i.e., zero tillage) to determine if the new production techniques changes the cost and benefit dynamics. In addition to this, there are several other useful publications of the same era that summarize the benefits and costs of shelterbelts in agricultural production in semi-arid regions, such as the Canadian Prairies. These include works by Baer (1989), Brandle et al. (1992b), and Kort (1988), which also provide overviews of shelterbelt benefits and costs but the researches note that these are prior to the zero tillage era. This change in agricultural management practices as well as a current focus on GHG's resulted in this research on the costs and benefits of shelterbelts under current agricultural management practices. Before agriculture producers are likely to adopt shelterbelts, they must be motivated to consider adoption of a new cultural practice (such as planting shelterbelts). They typically seek information on the economic consequences of their decision and make decisions based on whether to adopt new practices if they see the new practice as offering net returns (Cary and Wilkinson, 1997; Yang and Zhu, 2013). Information commonly sought by landholders when deciding whether or not to adopt planting shelterbelts includes their biophysical requirements, the opportunity costs incurred, and the infrastructure available. Evaluation of this information is influenced by the socioeconomic status, attitudes and values of the landholder. In the Canadian Prairies, programs have traditionally been publically funded and provided extension services to producers to encourage the adoption of shelterbelt trees (Kulshreshtha et al., 2006). With the discontinuation of the shelterbelt center at Indian Head, Saskatchewan, there is less support and promotion of shelterbelts available to agricultural producers (Kulshreshtha and Rempel, 2014).

Shelterbelts have the potential to play a role in reducing the impact agriculture has on the environment through carbon sequestration (Desjardins et al., 2001). The Paris Agreement is an agreement that has focused is to reduce the impact of industrialized activities on the environment with the objective to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty (European Commission, 2015). Shelterbelts could play a role in meeting this objective within the context of industrialized agriculture if agricultural producers are able to identify and see sufficient benefits from the incorporation of shelterbelts into their operations.

Canada signed onto the Copenhagen Accord in December 2009, where it committed to reduce its GHG emissions to 17% below 2005 levels by 2020 (Environment Canada, 2013). As a part of this commitment, the federal government created the Agricultural Greenhouse Gases Program (AGGP) which supported projects that will create technologies, practices and processes that can be adopted by farmers to mitigate greenhouse gas (GHG) emissions. These projects were also expected to help farmers increase their understanding of GHG emissions and how they can help to mitigate GHG (AAFC, 2016). This research was funded through this program. Four major ecosystem services and environmental benefits of agroforestry systems, such as shelterbelts are: (1) carbon sequestration (Amichev et al., 2016; Baah-Acheamfour et al., 2016;), (2) biodiversity conservation (Lovell and Sullivan, 2006), (3) soil enrichment (Kulshrestha and Kort, 2009). and (4) air and water quality (Jose, 2009). In particular carbon sequestration is of interest under the current federal government policy plans for GHG mitigation and carbon taxation.

It is noted that there is a sparsity of practical suggestions and data about how agroforestry policy and programs related to shelterbelts can be more effective by responding to the concerns and values of landholders. Therefore, the objective of this research is to explore the perception of producers and landowners with respect to shelterbelts costs and benefits on Saskatchewan farms and how these perceptions affect their adoption and / or retention decisions. Both private and social costs are included in this investigation. Additionally, a literature review is included with different costs and benefits of three types of shelterbelts commonly used within an agricultural operation -- farmyard, field, or livestock shelterbelts.

Review of the Impact of Shelterbelts in Agricultural Operations

Potential benefits and costs of shelterbelts

Shelterbelts can play an important role in agricultural production and historically have been essential on the Canadian prairies for the purpose of erosion mitigation. They 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). Shelterbelts are typically categorized into three categories based on the farm operations: home / farmyard shelterbelts, field shelterbelts, and livestock shelterbelts. Therefore, the goal of this study was to identify the perceived costs and benefits of these three types of shelterbelts in Saskatchewan.

Shelterbelts around farmyards

Shelterbelts around farmyards help to shield inhabitants, farm buildings, and infrastructure 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). Furthermore, property values may potentially increase for more "beautiful" yards if the sale of the property is based on the buyers desire to reside 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 pose an additional cost (i.e., tree removal) to the purchaser, resulting in a potentially lower land value. In addition to the increased desirability of yard sites with trees, there may also be health benefits for the residents of the farmstead. Some potential health benefits include the reduced inhalation of windborne particles (i.e., airborne sediment) (Mao et al., 2013; Abrahams, 2002), reduced pesticides drift into the yard site (Ucar, 2001), and potentially mental health benefits from enjoyment of the yard (Nielson and Hanson, 2007). Most of the costs associated with shelterbelts in farmyards are related to establishment and maintenance of trees around farmyards, removal of dead trees, and snow removal, especially if shelterbelts trap snow inside the farmyard (Brandle et al., 2009).

Shelterbelts in crop operations

Using shelterbelts in crop production provides some positive benefits to producers but also imposes costs on them. Shelterbelts alter wind patterns and protect the crop from wind related stress, as well as altering moisture available to the crops related to snow capture (Kort et al., 2012). However, the response of specific crops to shelterbelts varies due to crop characteristics or shelterbelt design. Drought-hardy cereal varieties and corn have low positive yield responses to shelterbelts, forage crops display moderately positive yield responses, and specialty crops (i.e., fruits and vegetables) and lentils can be classified as highly positive in their response to shelterbelts (Kort, 1988). Brandle et al. (1992a) in their economic evaluation of shelterbelts, concluded that "it is unclear whether ... yield increase is sufficient to offset those costs associated with the cropland planted to trees."

With the adoption of zero till or minimal till for agricultural production, these management systems are often seen as able to replace or eliminate the need for erosion mitigation through other measures such as shelterbelts (Casement and Timmermans, 2007), which is resulting in shelterbelts being removed as they are deemed unnecessary or imposing cost or inconvenience to the producer (Kulshreshtha and Rempel, 2014).). However, even with the improvements and changes in technology, wind erosion still affects Prairie soils each year (Casement and Timmermans, 2007) and shelterbelts play a role in mitigating the amount of soil loss through erosion prevention (Brandle et al., 2004). In crop production, there are two major avenues for benefits from shelterbelts that can translate into increased yields: (i) reduced wind erosion and wind damage (Brandle et al., 1992), and (ii) role in improving soil moisture through more even snow distribution in fields (Kort et al., 2012).

In dry years, the soil is more prone to suspension by the wind resulting in erosion and sandblasting of crops by suspended soil particles (Bennell and Verbyla, 2008). This may lower yields and protein content, cause delayed maturity, or even mortality (Kort, 1988). Shelterbelts trap suspended dust/soil particles and help to reduce the physical damage to crops by soil erosion (Cleugh, 1998). In addition to sandblasting and damaging established crops, small seedlings can physically be buried under deposited sediments resulting in increased seedling mortality. However, this would be an extreme case, but would be possible particularly in high tillage systems (i.e., organic production) (Cleugh, 1998). Another positive impact of shelterbelts could also include protection from winds to crops that are swathed and left in the field to dry

(Kort, 1988). 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.

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 speed, 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 soil moisture regime in semi-arid climates, such as that of the Prairies.

On the cost side, in today’s industrial scale agricultural production, large size of the equipment makes maneuvering around shelterbelts a challenge, particularly in the middle of the field, which imposes additional costs due to overlap and / or missed areas (Taylor, 2010). This directly translates into increased time in field as well as an increase in the amount of inputs (i.e., seed, fertilizer, fuel, etc.) that is required for a field with shelterbelts in the middle of the field, compared to one without. Additionally, shelterbelts take land out of agricultural production, which reduces the total amount of area in crop production per field (Brandle et al., 1992b). Finally, additional cost associated with maintenance activities for shelterbelts, such as root pruning, may be used to help reduce the competition between shelterbelt trees and crops (Kort, 1988); however, additional maintenance of shelterbelts is labor and cost intensive, particularly in the early years (Baer, 1989), which must be borne by the producer and acts as a major barrier to the adoption of new shelterbelts as well as a discouragement to retain poorly maintained shelterbelts.

Shelterbelts in livestock operations

Shelterbelts in livestock operations provide both costs and benefits to the operations. Shelterbelts provide an opportunity to improve the quality of life for the livestock raised within a pastoral setting through providing shelter (PFRA, 1980), improving feed use efficiency (Poppy, 2003), reduced mortality rates (Broster et al., 2010), improved forage and pasture crops (Sharrow et al., 2009) and, and increased/improved onsite water quantity (Pomeroy and Gray, 1995). Finally, shelterbelts placed around water bodies, whether natural or man-made (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 as it would reduce the need to transport water from off-site sources.

Some of the costs or negative impacts associated with shelterbelts in livestock operations include: fencing and repair costs (Brandle et al., 2009), habitat for predators of the livestock (Laporte et al., 2010), and shrub encroachment Brandle et al., 2009).

Landscape level benefits

Incorporating shelterbelts into management regimes has the potential to improve the ecological health of agricultural landscapes (Lovell and Sullivan, 2006) and overall improve production regimes which are beneficial to both the private land owner and society as a whole. One of the major environmental benefits is the provision of ecological goods and services to producers as well as to society (Kohli et al., 2008). These include: carbon sequestration (Schoeneberger, 2009), maintenance of biodiversity both above (Lovell and Sullivan, 2006) and below ground (Banerjee et al., 2016), and protection of soil and water resources (Kulshreshtha and Kort, 2009). In addition, potential for increased property values (Ma and Swinton, 2011), and improved recreational opportunities (i.e., hunting, bird watching, hiking) (Kroeger and Casey, 2007) are also credited to shelterbelts in and around yard sites or where people live. Providing habitat for pollinators is considered a benefit recognized by farmers that could be promoted to increase shelterbelt adoption (Brodst et al., 2009). Shelterbelts also provide an increased level of underground biodiversity (Banerjee et al., 2016), water infiltration, and soil moisture retention compared to the mono-culture that surrounds them; this is due to the extensive rooting zones and aboveground biomass of the perennial plants associated with shelterbelts (Lovell and Sullivan, 2006). Another landscape level benefit is reducing erosion in the landscape. This is desirable because it also provides societal and environmental benefits, such as reduced sedimentation of waterways (Kulshreshtha et al., 2006), reduced runoff from agricultural activities including fertilizer and pesticide (Ucar, 2001), and suspended soil interception (Brandle et al., 2009).

Survey Design and Evaluation

A survey of farmers in Saskatchewan was undertaken in 2013 to solicit their opinions on the costs and benefits related to shelterbelts as a part of agricultural operations. 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 the costs and benefits that influence producers' management decisions related to shelterbelts. Various potential factors related to the market and non-market costs and benefits, including areas such as environmental, social, agronomic, political, and economic spectra, were included in the survey questions.

The survey sample was randomly selected from all areas of the agricultural region of Saskatchewan. Potential survey participants were randomly selected from a database of tree order records from 1925 to 2009 from the Indian Head Shelterbelt Center, where farmers and landowners were able to order subsidized trees from through the PFRA free tree program. Using the order information, an algorithm randomly selected townships from those agricultural areas with trees orders, as described in Amichev et al. (2015). From these townships, land owners within that township were contacted to see if they were willing to participate in the shelterbelt research. If they consented, their farm/shelterbelt was visited in the summer of 2013 and at this time they were given the opportunity to participate in the survey. Figure 1 shows a map of location of participants' home legal land.

Participants were asked their response for questions related to the costs and benefits of their shelterbelts. These responses were recorded on a Likert-Scale, where 5 is the highly positive, 4 is positive, 3 is neutral, 2 is negative, and 1 is highly negative. Some examples are shown in Table 1.

The Likert-scale questions were created using the literature review of benefits and costs of shelterbelts. Questions were related to the three main types of shelterbelts: farmyard, field, and livestock. There were 26 Likert scale questions. They also included both private benefits and costs as well as public benefits and costs to see how individuals viewed each factors influence on their management decisions.

Additional data collected included information about the farm operation and the participant's personal characteristics. These data were used to classify the operations as well as to compare them to the 2011 Census data. In total, there were 19 questions related to the participants and their farming operations.

Prior to the Likert scale ranking questions participants were asked to identify the costs and benefits of shelterbelts on their operations. There were 16 questions related specifically to their shelterbelts and the costs and benefits that they have had associated with the each type of shelterbelt. Example of an Open Question are: "Please describe any other costs you have had related to your shelterbelt"; "What benefits do you receive from your shelterbelts (List all that apply)?" Such questions covered several aspects of costs and benefits of shelterbelts as perceived by Saskatchewan producers.

Statistical Analysis

Survey administration and return rate

The overall return rate based on the total number of surveys handed out (110) was 56%. This included participants taking multiple copies of surveys to give to others involved in the farm (i.e. business partner, brother etc). Sixty-two surveys were returned in total. Of the surveys completed and returned, 61 were useable in the study as one response was discarded on account of incomplete information. Surveys were completed with participants face to face, over the phone, and independently depending on the preference of the participant. The two biggest challenges to getting surveys completed was 1) the time of farm visits occurred over the spring and summer months which is a very busy time for producers, and 2) the survey was quite long and time consuming.

Using the data collected in the Likert-Scale rankings, several analysis were done, including descriptive statistical analysis and correlation analysis of responses which was visually represented in mind map, and ranking of the response based on frequency.

Descriptive Statistical Analysis

Descriptive statistical analysis was used to evaluate the questions in the survey related to demographics of the farm operators and the farm characteristics. For each variable the following measures were determined: maximum, minimum, mean, and standard deviation. For continuous variables, such as age, number of years farming, farm size, farm land area rented, farm land area rented out, and age of shelterbelts, the descriptive statistical analysis was particularly useful in understanding the sample characteristics.

In addition, the demographic information on farm operator and farm was then compared to the 2011 Statistics Canada farm and farm operator data for Saskatchewan (Statistics Canada, 2012). This comparison showed that our sample was similar in farm type, size, farm operator age, farm operator gender, and amount of rented acres to the Statistics Canada estimates. The study sample participants included a wide range of farm size, age of operator, years of farming experience, and estimated shelterbelt age with sample mean being similar to that of the mean of the 2011 Farm and Farm Operator Statistics Canada Survey.

In addition to the descriptive statistical analysis and comparison to the census data, a correlation analysis of the Likert scale questions was conducted. The Likert scale ranking questions are related directly to the specific type of shelterbelts: field, livestock, and farmyard. For each of the Likert scale questions a number was assigned for the participants response between 1 - 5, with 1 being highly negative and 5 being highly positive. These translated numerical values were used for the correlation analysis.

From the correlation analysis a mind map was constructed to visually highlight the underlying connections in the data shown through the correlation of participant's responses. A mind map is a diagram used to visually organize information and the connections between different pieces of related information. It is a powerful graphic technique that can be applied to improve learning and clearer thinking, and has been applied in economics and business (Peneder 2008); Buzan and Griffith 2011), as well as in the health (Walker et al. 2007) and education fields (Buzan & Buzan, 1993). Mind maps can be used as a method to facilitate the understanding of difficult concepts or connections. In addition to the mind map construction, the survey responses were also analyzed based on the specific types of shelterbelts present and the costs and benefits specific to that type of shelterbelt. This is useful in that different types of shelterbelts are considered differently from a management perspective. This information is particularly useful if policies are going to be designed to encourage shelterbelt plantings and maintenance in the prairies.

Observations based on open questions

The open questions responses were analyzed by writing out each cost and benefit identified and recording the total number of participants who indicated that specific cost or benefit. Some of the most commonly cited benefits were wind protection for home (n=23) and snow management (n=19). The most commonly cited costs were labor required for maintenance (n=41) and planting (n=33). Costs were more recognizable and identified more frequently than benefits in the open section of the survey.

Results and Discussion

Correlation analysis and mind map

The correlation analysis between the Likert Scale ranking factors and a bivariate correlation analysis was undertaken for all of the questions in the questionnaire to determine which variables had significant levels of association between demographic data and the Likert-Scale rankings. The demographic data were related to the farm operator and the farm itself. The variables with the highest correlations included: farmer's age to the number of years farming experience, total farm size to amount of land rented or leased, and livestock protection to feed use efficiency (Table 2). No factors were identified with a strong negative correlation.

Figure 2 shows the mind map displaying the Likert ranking factors and their correlation to the other Likert factors; a bivariate correlation (r value) greater than 0.45 was used for the various factors. The mind map in this study was related to the factors participants ranked in the Likert scale ranking of the questionnaire. It was created to help to visualize the connections identified from the bivariate correlation analysis. It was formulated as a way to visually represent the underlying connections of the factors. A bivariate correlation analysis was conducted of the Likert-scale ranking questions to gauges the impact or influence of each of the factors in relation to the other factors. Another interesting connection drawn from the mind-map is that producers do seem to recognize, even if it is unconsciously, the interconnected nature of the landscape; however, since many of these connections are external to the operations they are very difficult for producers to quantify or include in shelterbelt management decisions at this time. The factors with the strongest correlation to each other were livestock protection (shelter) and livestock feed use efficiency (r= 0.737) and the sustainability of agriculture and biodiversity in the landscape (r=0.691). The factors related to livestock are specific to livestock shelterbelts and are benefits captured entirely by the producer. The sustainability of agriculture and biodiversity in the landscape are societal benefits that are very difficult to quantify or include in individual management decisions.

Additionally, strictly economic variables were correlated to each other but were not correlated to environmental or social variables. It is worth highlighting that two factors identified as the biggest economic costs (land taken out of production, and overlapping of seeding/spraying) were strongly correlated (r = 0.527) to each other but were not significantly correlated to other costs/benefits which included social or environmental costs and benefits. In contrast, the social and ecological/environmental variables had greater degrees of correlation and overlap with each other, with multiple variables being strongly correlated to several others. This is observable in the mind map through the amount of connections of factors and impacts present at each node (Figure 2). These mind map relationships highlighted that producers do not observe or recognize direct economic benefits from the ecological and social benefits of shelterbelts, which could affect shelterbelt adoption in general.

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. Many producers do not include landscape or environmental benefits into their own individual land management decisions. This is likely related to the fact that these benefits are not captured entirely by the producer but are also considered social or external benefits (i.e., externalities). 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. If shelterbelt agroforestry systems are to serve as a potential GHG mitigation tool in Canada, new policies and programs are needed that are specifically aimed at increasing the producer's awareness of the long-term economic impact of shelterbelts as well as finding ways to integrate the associated social and environmental benefits of shelterbelt adoption and establishment in the Prairies into management decisions through internalization of the externalities (i.e., through subsidies).

Likert Scale Ranking of Costs and Benefits by Shelterbelt Type

Field shelterbelts

For the field shelterbelts a summary is shown in Table 4 that includes the Likert scale questions related to field shelterbelts and their respective mean, standard deviation, and number of responses. Stopping or slowing down soil erosion (score 4.00 positive) followed by creation of microclimate around shelterbelts was recognized as a positive benefit by a higher proportion of respondents (score 3.81). On the other end of the spectrum, overlapping of seeding and spraying around shelterbelts (score 2.6) followed by shelterbelts impact on irrigation efficiency (score 2.95) were the least perceived benefits.

Livestock shelterbelts

For the livestock shelterbelts, table 5 provides a list of all factors related to livestock shelterbelts and the mean response, standard deviation, and number of responses for each question. In this case, 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. As both of these are related to shelter for the livestock, this indicated producers' perception of a positive benefit to livestock production and thus for adoption of livestock shelterbelts is largely related to the protection and benefits that their livestock receive from shelterbelts. In this analysis 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 on decisions related to livestock shelterbelts.

Farmyard shelterbelts

Eight factors related to farmyard shelterbelts were included in the Likert-Scale portion of the survey. These factors can be seen in Table 6 where there mean, standard deviation, and number of responses to the question are included. The eight factors related to farmyard shelterbelts included: 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; and 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). 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 (Table 6). These factors for the farmyard shelterbelts rated very highly compared to the factors either for the livestock or field shelterbelts and indicated the importance of these factors in shelterbelt management decisions.

Observations from the open response questions on shelterbelts costs and benefits

Overall, the most frequently indicated costs in the open comment section of the survey were related to the initial investment of labor required for shelterbelt planting (n=33) and for maintenance (n=41). In addition, hazard for large equipment (n=11) was also indicated as a negative impact of shelterbelts. Soil erosion was cited by only 5 participants as benefit to them.

This may be indicative of a mindset that zero till/no till operations have replaced the need for the erosion control provided from shelterbelts. Most of the benefits identified were related to non-market social and environmental benefits later on in the life of a shelterbelt (i.e., wildlife habitat (n=15), and beauty of mature trees (n=7)).Overall, general identification of benefits was lower than the identification of costs. This indicates that as whole producers see shelterbelts as having more costs than benefits.

In addition to simply listing the costs and benefits, producers were also asked about the specific or actual financial cost of planning and maintaining shelterbelts. Very few producers were able to provide a precise set of information. 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. Even these producers were not able to account for all costs. These survey results indicated that many producers were not well informed on the direct monetary impact associated with shelterbelts. Increasing the understanding and knowledge of the economic impacts of shelterbelts may have the potential to influence shelterbelt adoption decisions under both the income and innovation diffusion paradigms.

There was also a lack of producer's identification of the landscape level impacts of shelterbelts within their operations. For example, many ecological benefits were not identified by the producers as costs or benefits 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 several producers as positive impacts. This illustrates that either producers are not aware of the suite of costs and benefits or since they are not directly compensated for such benefits, they are very difficult to include in their management decisions

Increasing the understanding of producers on the costs and benefits will be essential for policy (subsidy or taxes) and extension programing to be accepted and successful.

Conclusions

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 the benefits that accrue to them from farmyard shelterbelts; however, as farms grow larger and rural populations decline, so too will farmyard shelterbelts as there will be less and less farmers and associated farmyards. Many of the producers in Saskatchewan are also shifting from shelterbelt agroforestry systems to the use of other technologies for large scale agriculture operations, such as zero till and chemical fallow, indicating that field shelterbelts were no longer the preferred best management practice for some producers.

Shelterbelts provide many benefits to society but the results in this study showed that many of the benefits are not fully recognized, internalized, or understood by Saskatchewan producers. This highlights the fact that where social, environmental, or landscape benefits or costs exist, it is very difficult to expect individuals to recognize said benefits or costs in their management decisions. Evidence collected in this study identified a shift in the attitudes of producers related to shelterbelts in that many of the surveyed producers felt that shelterbelts were no longer an important or necessary aspect of agricultural production mainly due to changes in the scale of production and production technologies. However, this research also emphasized the lack of knowledge by producers about actual monetary costs and benefits of the environmental and social aspects of shelterbelts. Continued education and awareness surrounding the full suite of benefits associated with shelterbelts in agricultural landscapes is needed as many producers did not recognize many or any benefits associated with shelterbelts. Improving the education and awareness about the benefits of shelterbelts on the Canadian Prairies will be essential for a more widespread acceptance of any new policy (i.e., cap and trade, carbon tax, subsidy) program, aimed at improving shelterbelt adoption by producers.

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Figures

Figure 1- Locations of Surveyed Producers in Saskatchewan (Amichev, 2013)

Figure 2 An overview of the mindset of producers for adoption of shelterbelts on their farm. (Note: lines between variables indicate an identified correlation and the numbers on the lines are the r values from the correlation analysis.)

Tables

Table 1. Selected examples of Likert-Scale used in the study

Q.: Shelterbelts impact on crop yields is:	Q.: Species biodiversity in shelterbelts in agricultural landscapes.
☐ Highly Negative	☐ Highly Negative
☐ Negative	☐ Negative
☐ Neutral	☐ Neutral
☐ Positive	☐ Positive
☐ Highly Positive	☐ Highly Positive

Table 2. Variables with high, positive correlations.

Variable 1	Variable 2	Pearson Correlation	Significance level	Number of respondents
Age	Years of farming	0.77	0.01	61
Farm Size	Acres rented or leased	0.86	0.01	60
Livestock protection from shelterbelts	Shelterbelts impact on livestock feed use efficiency	0.74	0.01	49

Table 3. Descriptive statistics for selected variables for surveyed farmers in Saskatchewan in 2013.

Particulars	Unit of Measure	No. of Responses	Minimum	Maximum	Mean	Std. Deviation
Age	Years	61	23.0	87.0	55.18	16.07
Years of farming	Years	61	0	63.0	30.56	18.01
Farm size	ha	61	2.0	7,290.0	963.4	1,321.00
Rented or leased land	ha	60	0	2,835.0	272.6	559.60
Land rented or leased out	ha	61	0	291.6	14.70	43.90
Shelterbelt average age	Years	58	4.0	118.0	37.87	23.12

Table 4. Summary of field shelterbelt factors ranked by surveyed farmers in Saskatchewan in 2013.

Likert Scale Factor	Mean*	Standard Deviation	No. 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	3.72	0.84	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
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

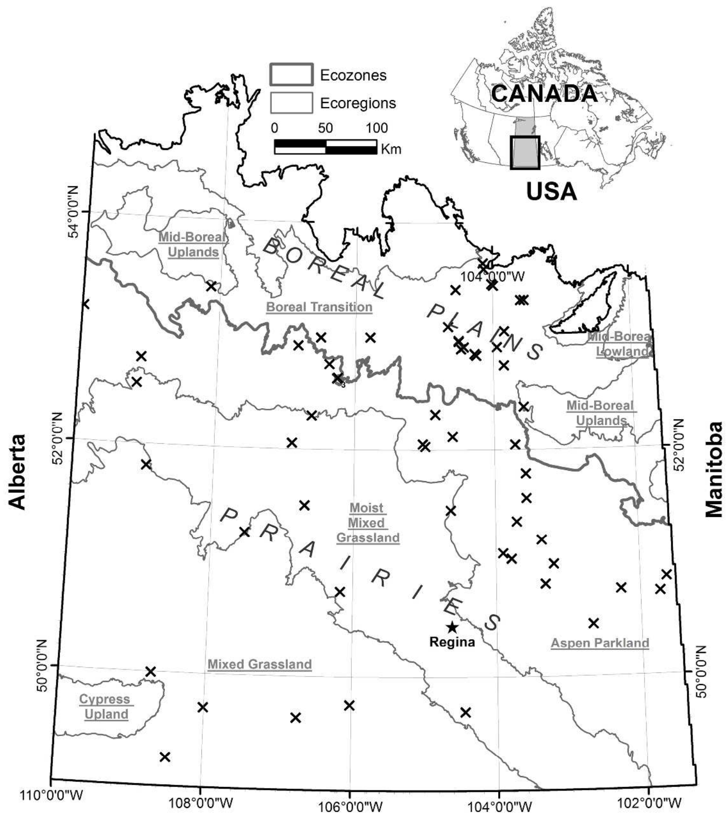
* Scores are based on a Likert Scale, where 5 is the high positive, 4 is positive, 3 is neutral, 2 is negative, and 1 is highly negative. A higher score depicts higher level of agreement.

Table 5. Summary of livestock shelterbelt factors ranked by surveyed farmers in Saskatchewan in 2013.

Likert Scale Factor	Mean	Standard Deviation	No. of Responses
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
Shelterbelts impact on land values	3.70	0.925	57
Shelterbelts impact on dugout recharge	3.63	0.787	43
Snow capture by shelterbelts	3.66	1.027	59

Table 6. Summary of farmyard shelterbelt factors ranked by surveyed farmers in Saskatchewan in 2013.

Factor	Mean	Standard Deviation	No. of Responses
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	3.7	0.952	57
Shelterbelts impact on dugout recharge	3.63	0.787	43



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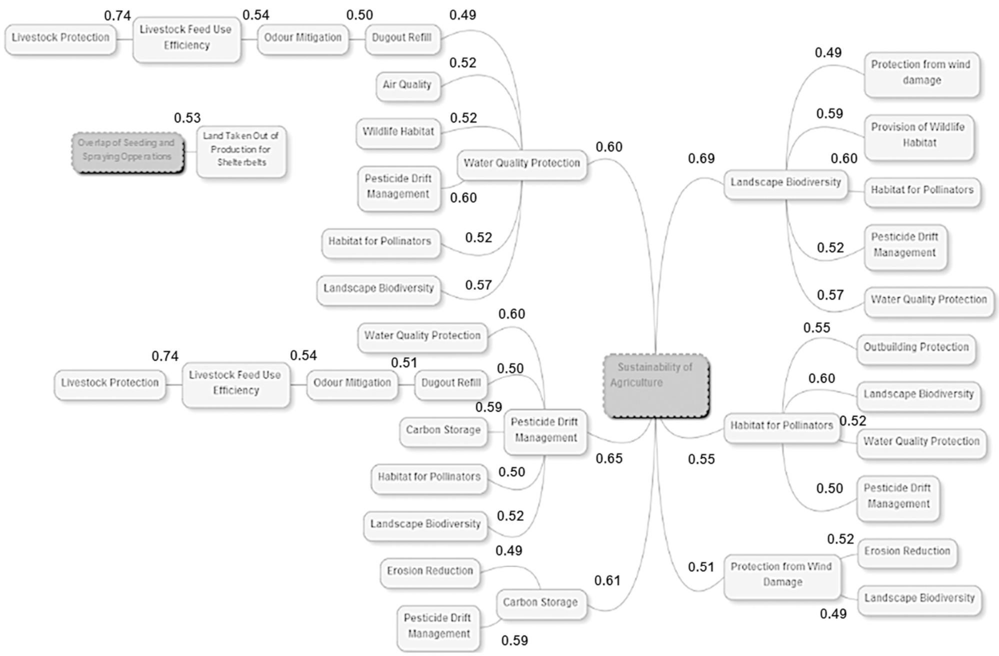

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