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Effects of shelterbelts on snow distribution and sublimation

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Abstract On the Canadian Prairies and the northern US Great Plains, snow is an important component of annual precipitation, sometimes constituting over 40% of the total, although there is much annual and regional variability. Much of this snow is transported by wind, causing substantial sublimation losses, which are reduced by obstacles and topographic features on the landscape that reduce snow transport and trap snow. Agroforestry configurations trap snow and reduce the amount and distance of snow movement and, because of this, reduce the amount of moisture lost to sublimation. The planning of agroforestry measures should therefore take into account their effects on snow hydrology. In this study, the effects of shelterbelts on snow quantity and distribution are shown over multiple years, including a number of locations in Manitoba and Saskatchewan. Results show that snow transport reached equilibrium in 400 m or less (i.e., that sublimation rates were at their maximum beyond 400 m leeward of a shelterbelt). Also, in a paired landscape inventory, the landscape with shelterbelts had 29% more snow water equivalent (SWE) than the unsheltered landscape. Site-specific meteorological data was used in the Prairie Blowing Snow Model, now a component of the Cold Regions Hydrological Model, to calculate the effects of agroforestry configurations on snow water conservation. Modeled snow distribution agreed well with measured snow at Conquest, Saskatchewan, in the winter of 2009/2010. Using actual weather data for the same location for the period 1996–2011, the model calculated the annual sublimation from 200 m wide fields protected by shelterbelts to be up to 12.5 mm less than similar unsheltered fields.

Keywords Snow · Sublimation · Hydrology · Shelterbelt

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Introduction

Snow is an important part of annual precipitation in many northern agricultural landscapes. On average, it represents 20–40% of annual precipitation in the northern Great Plains of the US and the central prairies of Canada (Aase et al. 1976; Pomeroy and Gray 1995), varying greatly from region to region (Table 1). Much of this snow is redistributed by wind, so that bare fields are sometimes seen in mid-winter. Other climatic

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Table 1 Thirty-year climate normals (1971–2000) for precipitation and wind from Environment Canada weather stations near the sites at which snow measurements were made in this study (Environment Canada, http://www.climate.weatheroffice.ec.gc.ca)

Location of snow measurements	Nearby weather station	Snow (mm year^{-1})	Rain (mm year^{-1})	Wind speed (km h^{-1}) (Jan–Feb average)
Conquest, SK	Outlook PFRA	78	260	14.4
Indian Head, SK	Indian Head CDA; Indian Head PFRA	119	330	15.0
Lyleton, MB	Pierson; Brandon CDA	117	353	15.4
Carman/Winkler, MB	Morden CDA	120	416	13.2

conditions—wind speed and temperature—are also regionally variable, and these influence how much of the snow is transported. Although Table 1 shows the differences in long-term averages for four sites used in this study, annual differences in snowfall and transport are even greater.

Although snow still on the ground in the spring infiltrates into the soil or runs off, a significant amount can be lost to sublimation during the winter. Sublimation, the phase change from snow to water vapour, depends exponentially on wind speed (Pomeroy and Gray 1995), and therefore a large majority of it occurs while it is being transported by wind, with very little sublimation occurring from stationary snow. Pomeroy and Gray (1995) estimated that, in a given wind event, over 72% of blowing snow may be sublimated during transport, so that snowdrifts would represent less than 28% of the transported snow. In Saskatchewan agricultural fields, 15–41% of annual snowfall was reported to be lost to sublimation (Pomeroy and Gray 1995), as much as 10% of total annual precipitation. According to Greb (1980), one-third of snowfall, on average, is blown off agricultural fields in the US Central Great Plains.

The amount of snow transported depends on wind speed and other factors, including snow depth and condition, as well as surface roughness caused by crop residues or other vegetation. Sublimation rates further depend on temperature and humidity (Pomeroy and Gray 1995). The fetch at which transported snow reaches its equilibrium was estimated by Pomeroy and Gray (1995) to be at least 300 m in the northern prairie regions, which had relatively high snowfall, or in fields where there was sufficient crop residue to retain a significant depth of snow. However, equilibrium was not reached until 1 km for fields in which there was little residue or in regions with less snowfall and therefore less snow to be transported. In comparison, Tabler (1994) calculated fetches of over 2 km for equilibrium, based on modeling snow transport in Wyoming. Clearly, field measurements and model verification are needed to determine the reduction of sublimation for different fetches under prairie field conditions.

Shelterbelts are significant barriers to snow movement on the prairies, so that the last snow to melt in the spring is usually seen behind tree rows. Snow trapping is a major reason that shelterbelts are planted around farmyards, along laneways and farm roads, as well as along major highways (Shaw 1988). Trapped snow is also an important contributor to improved crop yields near shelterbelts (Kort 1988) and provides recharge of surface and groundwater. Scholten (1988) showed that shelterbelt design and management that increased porosity, not only decreased the leeward snowdrift depth, but also the total amount of snow trapped.

Snowdrift data are reported here for Canadian Prairie shelterbelts over multiple years from which the effect of field width on snow trapping was determined and the effects of shelterbelts in reducing sublimation losses was calculated. Shelterbelt design factors (species and porosity) that affected snow trapping efficiency and regional and annual variability were also measured since these factors also affect the ability of shelterbelts to reduce snow transport and sublimation.

The effects of the most important variables on the transport of snow and its resulting loss to sublimation and deposition to snowdrifts have been modeled in a comprehensive Prairie Blowing Snow Model (PBSM) (Pomeroy and Li 2000), which was found to accurately predict snow accumulation in prairie and Arctic environments. This model, a module of the overall Cold Regions Hydrological Model (CRHM)

(Pomeroy et al. 2007), permits the use of standard meteorological datasets to model snow redistribution by wind on different landscapes. It was successfully used by Fang and Pomeroy (2009) on a Saskatchewan wetland landscape by aggregating pixels into landscape units, resulting in accurate simulations of end-of-year snow, taking into account complex interactions among the landscape units, based on both topography and vegetative cover. This model was therefore considered to be suitable for modelling snow redistribution on agricultural fields with shelterbelts.

Materials and methods

Measurement of snow as affected by different shelterbelts

Snow depth measurements were made leeward of Manitoba and Saskatchewan shelterbelts, as listed in Table 2. The climate normals for these areas were determined from the closest Environment Canada weather stations (Table 1). These measurements were made to compare snowdrifts by region, by year and by shelterbelt structure. The measurements consisted of snow depths measured at intervals of 3 m along transects perpendicular to selected shelterbelts. For most shelterbelts, three transects were measured, but for more detailed measurements, five transects were used. The transects included measurements as far as 15 m windward of the shelterbelts and as far as 42 m leeward. This resulted in snowdrift profiles from which snow depth, width and cross-sectional area could be determined.

Table 2 Dates and locations for snowdrift measurements reported in this study

Number of shelterbelts	Date	Region
4	Feb. 11–12, 1986	Carman/Winkler, MB
19	Feb. 6–8, 1989	Conquest, SK
3	Jan. 23, 1992	Carman/Morden, MB
2	Jan. 28–29, 1992	Indian Head, SK
8	Feb. 5, 1992	Lipton, SK
12	Feb. 17–18, 1992	Conquest, SK
3	Feb. 23, 2011	Conquest, SK

Snow water inventory on sheltered and unsheltered land

On February 23, 1989, a snow survey was conducted on two sections of land (each 259 ha) near Conquest, Saskatchewan, to determine the increased snow quantity due to the reduction of sublimation on the sheltered section. One of the sites had no shelterbelts so that snowdrifts occurred only in ditches and a few depressional areas. The other section was fully sheltered with multiple caragana (*Caragana arborescens* Lam.) field shelterbelts on all four quarter sections (Fig. 1), a total of 19 shelterbelts. The unsheltered section was bordered by other unsheltered fields, while the sheltered section was bordered by other sheltered sections. There was a distance of approximately 10 km between them.

The snow survey was conducted by determining snow depths and snow density in sampling patterns, so as to account for all major depositions of snow. On the sheltered section, snow depth adjacent to the shelterbelts was measured in three snowdrift transects per shelterbelt. Similarly, transects were measured through ditches and across roadways, where snowdrifts had accumulated. Mid-field snow depths were measured in a grid on both sections. Snow density was determined by extracting snow cores from snowdrifts and from mid-field locations, melting them indoors and measuring their volumes. Densities were determined separately for samples from snowdrifts and mid-field locations. The densities were then multiplied by the snow volumes (average depth $\times$ area) for the respective features to give the water volume. The average snow depths for the features were also multiplied by the density to give the snow water equivalent (SWE), the equivalent depth of liquid water contained in the snow pack.

Comparison of actual and modeled snow distribution

On February 21–23, 2011, snow was measured adjacent to single-row caragana shelterbelts at Conquest, Saskatchewan, some of which had green ash (*Fraxinus pennsylvanica* Sarg.) and American elm (*Ulmus americana* L.) trees interspersed within the rows. The accumulated snow was compared to PBSM model simulations for the same fields for the 2010–2011 winter. Snow was measured in three east–west transects across two sites. One site was a widely spaced shelterbelt site,

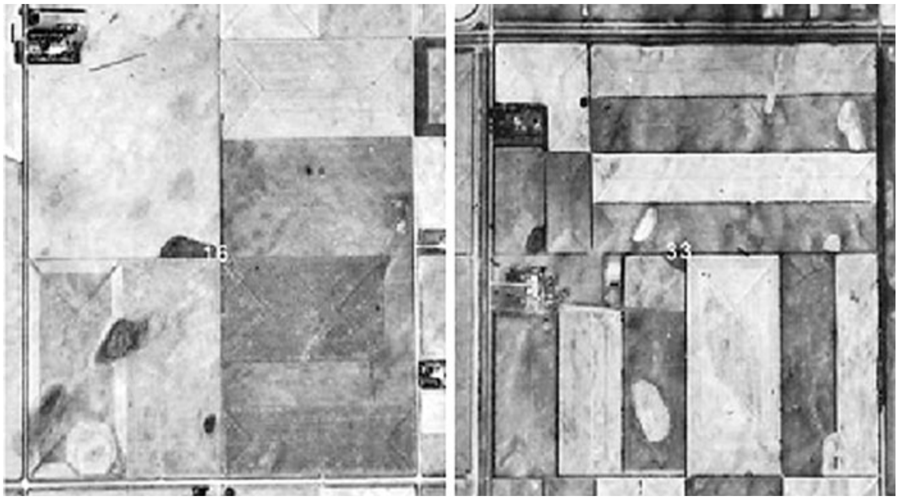

Fig. 1 1986 Aerial photo of the two sections of land, each 1,600 m × 1,600 m, used in the snow water inventory. The field centers are 51°28′56″N, 107°21′07″W and 51°31′30″N, 107°12′41″W, respectively

which had a north–south shelterbelt in the middle of a half-section parcel of land (i.e., 1,600 m × 800 m), thus bisecting it into two fields of 800 m × 800 m each. The other site was a parcel of land of 1,016 m × 800 m which included five north–south shelterbelts, with two fields 133 m × 800 m and one field each of 200 m × 800 m and 550 m × 800 m. On this site, snow was measured in three fields and adjacent to two shelterbelts. In the transects, snow depth was measured at 1 m intervals and snow density was also determined. Cores for snow density were extracted with a Rickly Prairie Snow Sampling Tube (Rickly Hydrological Company, Columbus, Ohio) and were weighed in the field with a spring scale. Snow density was determined at 2, 5, and 10 m from each shelterbelt, as well as at mid-field.

Meteorological data was obtained from Environment Canada for the nearest weather stations at Outlook and Rosetown, Saskatchewan. These data consisted of hourly air temperature, relative humidity, wind speed and daily precipitation. Incoming shortwave radiation, required by the PBSM, was not measured at either one of the stations, but was estimated according to the method of Annandale et al. (2002) in the CRHM.

The PBSM model used the observed crop residue, the fetch and the meteorological data as inputs to predict snow distribution on the sites. Shelterbelts were considered to be sinks for transported snow, while the crop fields were designated as sources of blowing snow (Fang and Pomeroy 2009). The snow distribution was then simulated by the model for the entire winter (October 1, 2010 to April 14, 2011).

Modeled snow distribution in different shelterbelt scenarios

Using 15 years of meteorological data from the Outlook, Saskatchewan weather station, the PBSM model compared the difference in modeled snow distribution under three shelterbelt scenarios on a half section of land (1,600 m × 800 m): (a) no shelterbelts on two fields of 800 m × 800 m; (b) three north–south shelterbelts dividing the land into four fields of 400 m × 800 m each; (c) seven north–south shelterbelts dividing the land into eight fields of 200 m × 800 m each. For all the scenarios, it was assumed that the vegetation in the crop field was 0.15 m high wheat stubble. The fetches were assumed to be greater than the field widths by a factor of 1.5 to reflect the fact that winds are not normally perpendicular to the shelterbelts.

Results and discussion

Effect of distance between shelterbelts on trapped snow and sublimation

Greater fetches were expected to result in larger snowdrifts. The effect of field width on the amount of

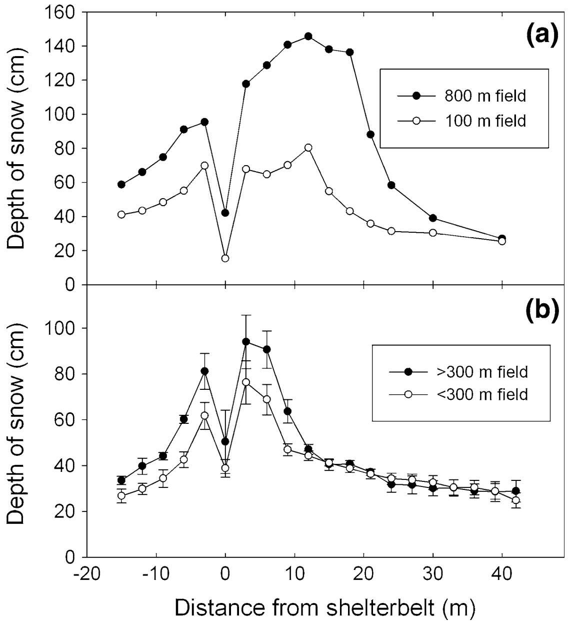

Fig. 2 Depth of snow trapped by shelterbelts as affected by upwind field width for **a** two similar shelterbelts at Winkler, Manitoba on February 12, 1986, **b** caragana shelterbelts at Conquest, Saskatchewan on February 17–18, 1992. The *bars* represent the Standard Error of the Mean for field widths <300 m ($n = 5$) and field widths >300 m ($n = 4$)

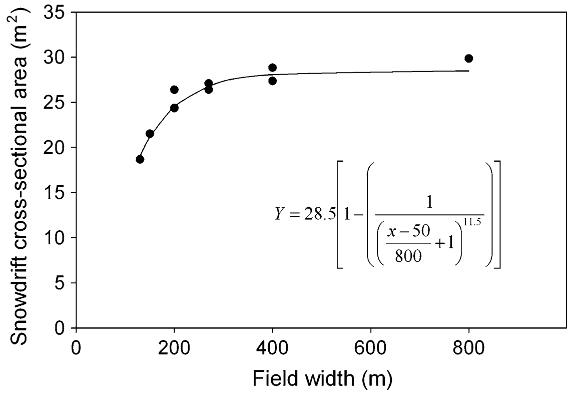

Fig. 3 Regression equation for the total snow trapped by nine caragana shelterbelts, as affected by field width, at Conquest, Saskatchewan, February 17–18, 1992. The upwind border for each shelterbelt was another shelterbelt. R^2 value for the regression was 0.94

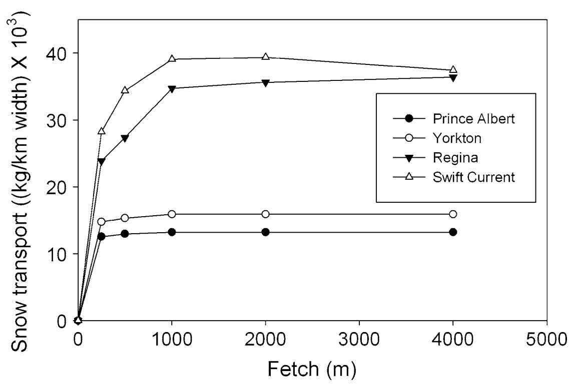

Fig. 4 Variation in mean annual snow transport with fetch distance at four Saskatchewan stations on fallow fields (Pomeroy and Gray 1995, p. 90)

snow trapped was determined for a number of years and locations. On February 11–12, 1986, snowdrifts were measured adjacent to two similar shelterbelts, differing in fetch. The shelterbelts were on the same parcel of land near Winkler, Manitoba and consisted of caragana planted between alternating green ash and American elm trees. The snowdrift was much larger leeward of the 800 m wide field than the 100 m wide field (Fig. 2a), with snowdrift cross-sectional areas of 34.4 and 13.8 m^2, respectively, assuming a 20 cm open-field snow depth.

At Conquest, Saskatchewan, average snowdrifts were measured on February 17–18, 1992 for nine similar caragana shelterbelts that included five with narrow field widths (<300 m) and four with wide field widths (>300 m). The average depths were significantly less for narrow field widths (Fig. 2b). The cross-sectional areas were 9.1 m^2 for the narrow field widths and 13.0 m^2 for the wide field widths, assuming a 25 cm open-field snow depth (i.e., the cross-sectional areas above 25 cm in height were calculated).

These same data were analyzed as individual fields using regression analysis in which the snowdrift cross-sectional areas were regressed on the field widths for the nine fields (Fig. 3). The snowdrift cross-sectional areas were 35 m^2 for the largest field widths. The data and regression lines showed that the largest snowdrifts occurred leeward of wide fields of 400 or 800 m.

Pomeroy and Gray (1995) (Fig. 4) concluded that, when the fetch is greater than 500 m (more or less, depending on conditions), snow transport is stable—the snow picked up by the wind is balanced by the snow that is deposited and/or sublimated. These values (400 m in Fig. 3 and 500 m in Fig. 4) were smaller than the maximum transport distance for snow of 3,000 m suggested by Tabler (1994) and emphasized that sublimation losses over relatively short distances can be substantial.

Fig. 5 Snowdrift size related to fetch at Lyleton, Manitoba. Fetch is greater than field size because the wind causing the snowdrifts was not perpendicular to the shelterbelts, originating from the *lower left* of the figure

The effect of fetch on snowdrift size can clearly be seen in Fig. 5, an aerial photo of Lyleton, Manitoba, in which a series of shelterbelts of similar design, shape and size clearly show the effect of fetch for snow that was transported from the lower left of the photo, with the shelterbelts in the foreground having much larger snowdrifts when the fetch was large (i.e., the field is unsheltered to the left) compared to those in which the fields were narrower.

The existence of snowdrifts implies that significant sublimation has likely occurred and larger snowdrifts imply a greater loss of moisture. Creating smaller fields bordered by shelterbelts to trap snow reduces the size of fields and therefore also reduces sublimation losses (Fig. 5).

Snow water inventory on sheltered and unsheltered land

It was hypothesized that two parcels of land in the same region, one sheltered and one unsheltered, would have a measurable difference in the SWE on the land, the sheltered parcel having a greater snow load than the unsheltered parcel, mainly due to an expected reduction in sublimation. Two sections of land, for which the total snow load was inventoried on Feb. 6–8, 1989, showed that the sheltered section had 29% more SWE (Fig. 6). Because crop stubble height was similar for both parcels, the average mid-field snow depth (14.0 cm) was the same. The "open-field snow" in Fig. 6 was less in the sheltered section because there was a smaller open-field area, with a greater area being

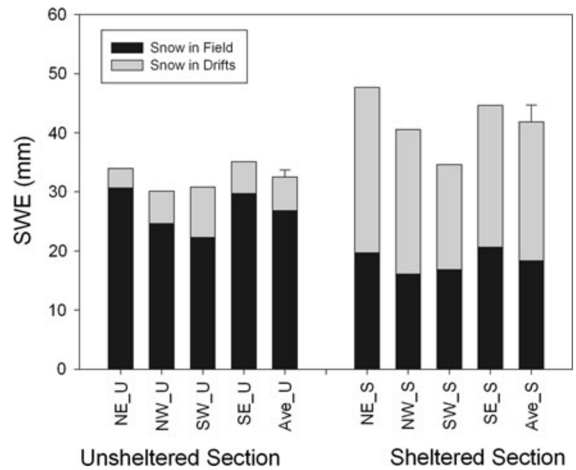

Fig. 6 Total water measured in snow on two fully surveyed, nearby sections of land (one "section" is 260 ha and one "quarter" is 65 ha). The *bars* represent the Standard Errors, based on the four quarter sections

occupied by shelterbelts and the snowdrifts adjacent to them. The increased snow water in the sheltered parcel was therefore to be found in the snowdrifts that were adjacent to the shelterbelts.

Comparison of actual and modeled snow distribution

Accumulated snow in Conquest, Saskatchewan fields with shelterbelts is shown in Fig. 7. It was found to be well-correlated to simulated snow distribution according to the PBSM model, with root mean square differences of 16.1 mm SWE. In the narrow shelterbelts site, the trapped snow in the shelterbelts had a SWE of twice that in the open field, when averaged over the shelterbelt snowdrift area (20 m $\times$ 800 m for each shelterbelt), while, in the wide shelterbelt site, it was three times that of the open field SWE. The snowdrift at the wide shelterbelt site was larger than in the other site, likely due to the wider fetch.

The differences between the modeled and actual SWE could be attributed to actual field conditions that could not be captured in the model (topography, residue height variability, gaps in shelterbelts, etc.) and to interpolations and estimations of incomplete meteorological data. Nevertheless, the good correlation between the actual and modeled SWE suggest that, if actual agroforestry systems can be described with sufficient accuracy, the PBSM outputs can

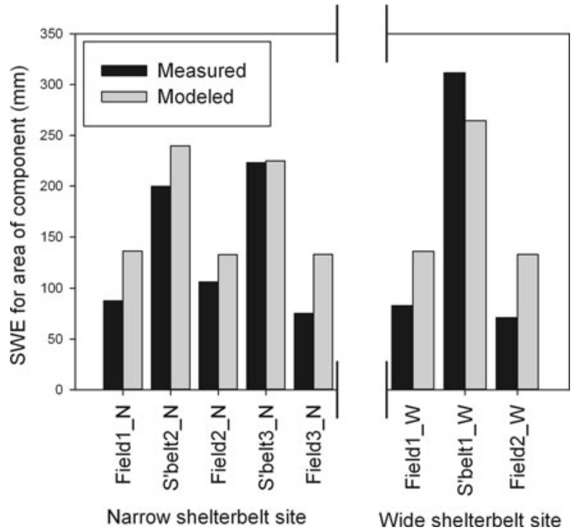

Fig. 7 Comparison of measured and modeled snow distribution in two shelterbelt sites. The shelterbelts were 133 m in the "narrow" site and the "wide" site had a single shelterbelt with fields 800 m wide on both sides. The snow was measured on February 21–23, 2011 and the modeled snow was based on the winter's weather data

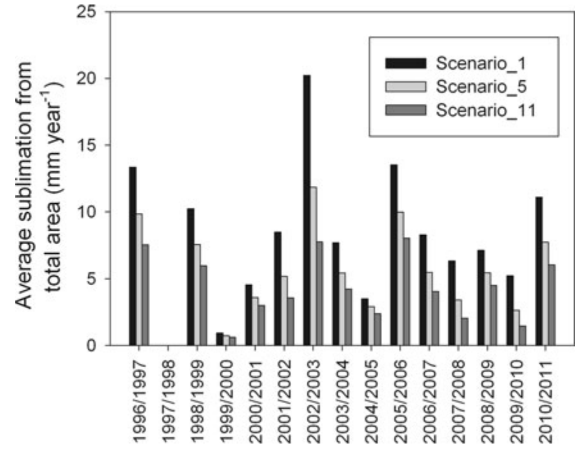

Fig. 8 Calculated sublimation from a half section of land (1,600 m × 800 m) with Scenario 1: no shelterbelts; Scenario 5: four shelterbelts and four equally sized (400 m × 800 m) fields; Scenario 11: eight shelterbelts and eight equally sized (200 m × 800 m) fields

provide good approximations of their effects on snow distribution. For instance, the model provides a way to assess the impact of various shelterbelt spacings on field snow accumulation and the impact of varying stubble height on snowdrift formation around shelterbelts.

Modeled snow distribution in different shelterbelt scenarios

Based on the good correlation between modeled and actual snow distribution at Conquest, Saskatchewan in 2010–2011, the PBSM model was used to estimate snow distribution over a 15-year period (1996–2011) for the same area for different shelterbelt scenarios, based on actual meteorological data provided by Environment Canada. Sublimation of snow under these conditions is shown in Fig. 8. The sublimation calculated by the model in Scenario 1 (no shelterbelts) represented 0–12% of the total SWE of the winter's snowfall, with a median value of 6.8%. In general, the loss of snow to sublimation calculated by the model was less than the values reported by Pomeroy and Gray (1995) or Tabler (1994). This may have been due to the fact that the Conquest area generally has less snow than more northerly and easterly regions (see Fig. 4) and that the assumed crop stubble height of 15 cm resulted in significant snow retention by the residue.

For the years modeled, the calculated annual sublimation of snow was up to 12.5 mm less in the narrowly spaced shelterbelts of Scenario 11 than in the no-shelterbelt scenario, with a median value of 4.3 mm and a total value over the 15-year period of 59.3 mm. The year-to-year variability of the impact of shelterbelts can be attributed to the meteorological differences among years. Sublimation rates depend on temperature and relative humidity, while the effective fetch depends on wind direction. If blowing snow events occur at night, when relative humidity is usually higher, or during very cold weather, or if the wind direction is parallel or at an acute angle to the shelterbelts, sublimation rates would be less and the shelterbelt impact in reducing sublimation would also be lessened. Although the reduction of sublimation by shelterbelts in these scenarios was not large, its significance is magnified in drought years when growing-season rainfall is low. In such years, extra moisture from snow results in significant improvement in crop germination, growth and yield (Kort 1988). Extra snow in recharge areas protected by shelterbelts can also significantly improve the recharge of aquifers.

Haehnel and Liston (2004) reported that the model SnowTran 3D, which was developed for snow transport modeling under Arctic conditions, was successfully used integrally with GIS software. Work of future importance would therefore be to use or develop the PBSM in spatially explicit scenarios, so that agroforestry systems could be modeled at a landscape level, rather than just as individual fields or shelterbelts.

Other variables affecting shelterbelt snow-trapping efficiency by shelterbelts

In the same way that the design of constructed windbreaks affects their efficiency (Tabler 1994), shelterbelt properties affect the snowdrifts formed. Shelterbelt height is likely not one of the important factors, because typically sharp cornices of snowdrifts show them to be in a pre-equilibrium stage. The snowdrifts in this study never approached equilibrium (Figs. 2, 9), as described for windbreaks by Tabler (1994). The largest snowdrifts reported here, including those on the windward side, had cross-sectional areas of slightly more than 30 m^2, while, according to Tabler's design criteria, a 5 m high caragana shelterbelt, assuming a porosity of 50%, would have equilibrium snowdrifts of 75 m in length and 90 m^2 in cross-sectional area.

The effect of shelterbelt porosity on snowdrifts was studied, as it was affected by shelterbelt species, spacing and shelterbelt thinning. Snowdrift measurements made in 1992 for shelterbelts of different species that had been established on the same quarter section at Lipton, Saskatchewan, showed that the denser species—caragana and Siberian elm—had larger snowdrifts than the green ash shelterbelts (Fig. 9a). When green ash/American elm/caragana shelterbelts at Carman, Manitoba, were thinned in 1985, by removing the caragana and leaving only the alternating green ash and American elm at 2 m between trees, the snowdrifts were greatly reduced (Fig. 9b). Prior to thinning, the caragana had prevented persistence of the lower branches of the trees, so that the resulting trees-only windbreak had very little low-level resistance to the wind and very little snow-trapping resulted. These results accord with the findings of Scholten (1988) that dense shelterbelts have narrow deep snowdrifts and trap more snow than porous shelterbelts. The results also show the distribution of porosity in the shelterbelt to be important since high porosity in the lower part of the shelterbelt results in very little snow trapment (Fig. 9b).

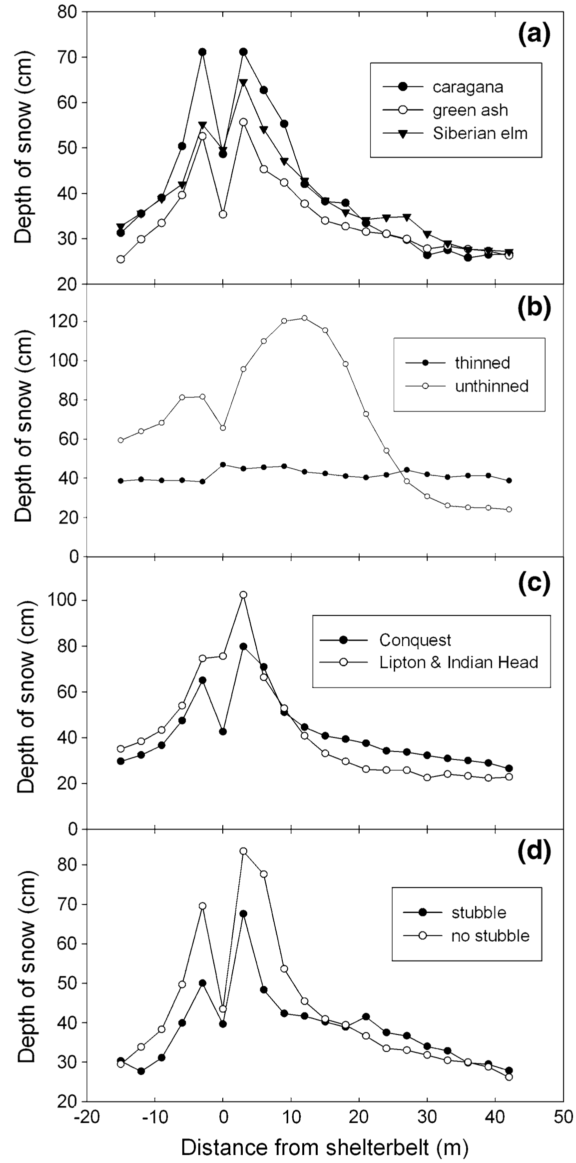

Fig. 9 Snowdrifts adjacent to **a** eight shelterbelts of three species at Lipton, Saskatchewan, measured February 5, 1992. **b** green ash/American elm shelterbelts with and without caragana at Carman, Manitoba, measured February 11, 1986 and January 23, 1992. Measurements are the averages of the two dates. **c** caragana shelterbelts at two Saskatchewan locations measured January 28 to February 18, 1992. **d** caragana shelterbelts downwind of fields with stubble ($n = 3$) or no stubble ($n = 9$)

Snowdrifts were measured in different regions because it was expected that there would be a major regional differences in annual snowfall and blowing snow events. In February, 1992, snowdrifts adjacent to similar caragana shelterbelts at Conquest, Saskatchewan and near Indian Head, Saskatchewan, which are about 300 km distant from each other, were substantially different in depth (Fig. 9c). Similar regional differences occurred in other years and snowdrifts varied greatly in size and orientation, because snowstorms that result in snow drifting are often localized.

Field conditions for snow drifting are greatly influenced by crop residue management since preserving a tall stubble cover on the field over the winter ensures that much of the snow will remain on the field, while short stubble or fall tillage results in the snow being far more easily transported. Snowdrifts adjacent to caragana shelterbelts at Conquest, Saskatchewan, that were measured in February, 1992 showed that snow depths were substantially less when the upwind field had significant crop stubble than when no stubble was present (Fig. 9d).

Shelterbelt snow-trapping efficiency is affected by these variables of porosity, region, orientation and field crop residue. The PBSM can take several of these factors into account, because it is regionally specific, depending on weather data from the nearest weather station, and because it considers field residue status. As well, shelterbelt orientation is partially considered by the fetch distance but, because wind direction is different from one storm to another, it is only partially accounted for. The PBSM simulations shown here assumed high shelterbelt snow trapping efficiency; however, by reducing the vegetation density in the shelterbelt simulation, the reduced snow trapping by porous shelterbelts, such as those that consist of green ash trees at 2 m spacing between trees, could also be simulated. The PBSM was therefore considered to be a useful tool in modeling the effects on snow by different shelterbelt designs and configurations.

Conclusions

Large sublimation losses from wind-transported snow were suggested by the paired landscape snow inventory which resulted in a measured increase of 29% in a sheltered section of land, compared with a similar unsheltered section, a value comparable with estimated snow sublimation losses of 15–41% reported in the literature. Lower sublimation losses were calculated by the Prairie Blowing Snow Model (PBSM) for Conquest, Saskatchewan, but the snow distribution calculated by the PBSM was well-correlated with measured snow. Shelterbelts reduced sublimation losses, according to agroforestry scenarios modeled with the PBSM and these reductions were greater when the shelterbelts were close together (i.e. 200 m) than for more widely spaced shelterbelts. Landscape-level planning of shelterbelts and other agroforestry options can therefore be used to reduce sublimation losses and increase the overall snow retained on the local landscape, which may provide direct moisture for the following year's crop or for the recharge of groundwater or surface water supplies. The successful use of the PBSM suggests that it can be useful to model and compare agroforestry scenarios throughout the prairies under actual and predicted meteorological conditions.

The results of this study show that landscape-level planning of agroforestry options can be used to manage snow distribution. Agroforestry can be used to keep snow where it is needed and prevent snow accumulations where it is not wanted. Low-porosity shelterbelts closer than 400 m apart are efficient snow traps and are useful for protecting fields, roads and farmyards or for recharging groundwater or surface water reservoirs or wetlands. The reduction of sublimation is greater when shelterbelts are closer together and shelterbelts that were less than 200 m apart were more effective than more widely spaced shelterbelts. Agricultural producers therefore need to decide on a spacing between field shelterbelts that will balance the benefit of snow conservation with the practicality of field sizes that are large enough to conveniently accommodate their farm equipment. The increased water resulting from reduced sublimation losses, especially during years of drought, represents a way to help drought-proof the prairie region in the face of the possible effects of a changing climate.

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