Multi-functional Windbreaks: Design Options and Economic Evaluation

June, 2012

Nottawasaga Valley Conservation Authority
Ontario Ministry of Agriculture, Food, and Rural Affairs

Acknowledgments
C. Brad Peterson Environmental Management and Landscape Architecture completed the windbreak characterization, profiles, generic designs and economic model update for this project.

1. Executive Summary

In 2011-2012, the Nottawasaga Valley Conservation Authority (NVCA) and the Ontario Ministry of Agriculture, Food, and Rural Affairs (OMAFRA) with funding through the provincial Lake Simcoe funding program undertook a multi-phase windbreak project. The primary goals of this project were to:

- Develop and deploy state-of-the-art windbreak designs which can be shown to reduce the wind effects of soil erosion;
- Offer an educational workshop for farmers and environmental service professionals on the benefits of multi-functional windbreaks; and
- Provide opportunities for farmers to demonstrate benefits of windbreaks through personal observation of crop yields and pest and disease problems over time.

The project components consisted of:

1. Project report that included a windbreak economic calculator and summary of demonstration windbreaks plantings
2. Two day multi-functional wind break workshop designed towards farmers and extension staff
3. Survey with farmers in the NVCA watershed to solicit input on the use of multi-functional windbreaks and windbreaks, and to assess interest and potential barriers and opportunities

A summary of each project component is expanded below.

Multi-functional windbreaks: Design Option and Economic Evaluation Tool

Completed by C. Brad Peterson Environmental Management and Landscape Architecture; this component details multifunctional windbreak/windbreak design, economic evaluation information suitable for farm operations in Simcoe County, and description of four windbreak case studies. It conceptually builds on the work of André Vézina of L'institut de Technologie Agroalimentaire, campus de La Pocatière, Québec. This aspect presents theory and concept for a number of generic designs for multi-functional windbreaks, based on the evolution of state-of-the-art development of similar windbreaks in Ontario and Québec. An economic simulation tool was used to determine economic opportunities of multi-functional windbreaks and windbreaks, updating the pre-existing 'Simulation tool to assess the economic impacts of agroforestry practices' for Simcoe County. The last component consists of design and development of demonstration windbreaks based on site-specific designs developed from generic designs.

Multi-functional windbreak workshop: January 17 and 18, 2012

The windbreak workshops were held on January 17, 2012 for agroforestry, forestry, and outreach staff and on January 18, 2012 for the agricultural community. The workshops, entitled "A New Perspective on Windbreaks: Multi-functionality Workshop" were held at the Nottawasaga Inn in Alliston, ON. The objective of the workshop was to provide professionals and the agricultural community with an introduction to the potential opportunities and benefits of multi-functional windbreaks and shelterbelts and to promote the concepts of multi-functional windbreaks and shelter belts, etc. The workshop topics included:

- Windbreak design and planting
- Benefits, costs and cost-sharing programs
- Maintenance and trade-offs
- Economic opportunities of multifunctional windbreaks and windbreaks.

Workshop presenters included André Vézina (L'institut de Technologie Agroalimentaire), John Kort (PFRA), Brad Peterson (C. Brad Peterson), Nathan Munn (GRCA), Jason Deveau (OMAFRA), Paul Day (Trees for Mapleton), and Shannon Stephens (NVCA). The January 17,

2012 workshop was also provided as an OMAFRA-produced webinar. The webinar presentations (wmv format) and presentations (as pdf) are provided online at http://www.wbvecan.ca/anglais/document.html.

Forty seven (47) agroforesty, stewardship professional/practitioners attended the January 17, 2012 multi-functional windbreak workshop. Present included staff from conservation authorities, OMAFRA, MNR, MTO, AAFC, municipalities, Trees Ontario, Trees for Mapleton, landscape architects/contractors, and non-government organizations. In addition, 22 people signed up for the webinar with attendance from conservation authorities, Conservation Ontario, University of Guelph, and provincial agencies.

Thirty seven (37) farmers attended the January 18, 2012 multi functional windbreak workshop. Various sectors were present at the workshop included potato, sod, organic, cash crop, hobby farm, and commodity groups from Simcoe, Durham, Peel, Grey-Bruce, etc. Further, Ontario Federation of Agriculture and the Christian Farmers Association were both present as was the Ontario Potato Board and the Holland Marsh Growers Association.

Agricultural community multi-functional windbreak survey results

Outstanding in Simcoe County is the agricultural community perception of windbreaks including multi-functional windbreaks. A survey was developed by OMAFRA and the NVCA to solicit input on windbreaks and their multi-functionality and to assess the interest, potential barriers, and opportunities within the community regarding windbreaks, in general. In addition, the outcomes of the survey may be used to assist Ontario-specific windbreak research and extension programs delivered by OMAFRA, Conservation Authorities, and various extension staff. The survey was distributed to three audiences: 1) a mail out to the general farming community in south Simcoe County, 2) the attendees at the January 18, 2012 multi functional workshop for the agricultural community and 3) distributed to the attendees at the Southwest Diagnostic Farm Days (July 4, 2011).

General conclusions from the surveys include:

- Participating agricultural community has a broad awareness of how windbreaks benefit property value and crop yields along with the positive correlation of windbreaks and on-field soil erosion.
- Windbreaks are generally older than 20 years old with a significant number of respondents indicated that they never completed maintenance on their windbreaks.
- Environmental cost share program (e.g. EFP) was not used extensively for the establishment of the windbreaks.
- Establishment of windbreaks was for on-field issues such as controlling soil erosion and crop yield improvements. ‘Multi functionality’ components, e.g. timber revenue source, were not considered.
- A common theme surrounding the removal of wind breaks was conflict with farming practices and ties to commodity prices.
- Removed wind breaks were predominantly 1-5 rows.
- 53% of mail in respondents indicated that they are not likely to build a new windbreak while only 27% indicated that they were very likely to plant a new windbreak.75% of the workshop respondents indicated that they were very likely to establish a new windbreak.

Table of Contents

List of Figures

List of Tables

2. Introduction

In 2011-2012, the Nottawasaga Valley Conservation Authority (NVCA) and the Ontario Ministry of Agriculture, Food, and Rural Affairs (OMAFRA) with funding through the provincial Lake Simcoe funding program undertook a multi-phase project to develop applications for multi-functional windbreaks within the NVCA watershed. A windbreak is essentially a barrier of trees and shrubs that help to slow down the speed of wind. Generally speaking, multifunctional agriculture refers to the non-trade benefits attached to agricultural production including environmental effects. Regarding windbreaks, such multi-functions include reducing wind associated soil erosion, protecting livestock, reducing building heating costs, creating favorable microclimates for field crops, providing opportunities for farm income diversification through biomass and market crops, and increasing aesthetic values, etc (Agriculture and Agri-Food Canada et al., 2008; Kort, 1988). In specialized cases windbreaks can also be used to disperse farm odours (Vézina, 2005).

The primary goals of this project were to:

1. Develop and deploy state-of-the-art windbreak designs which can be shown to reduce the wind effects of soil erosion and offer economic valuation of windbreaks to the farmer;
2. Offer an educational workshop for farmers and environmental service professionals on the benefits of multi-functional windbreaks; and
3. Provide opportunities for farmers to demonstrate benefits of windbreaks through personal observation of crop yields, and pest and disease problems over time.

Summary of the multi-functional windbreak workshop for farmers and environmental service professionals is provided in Appendix 1. The results of the producer-based survey to gauge the acceptance of, opportunities, and constraints around windbreaks are presented in Appendix 2 for the producers in the NVCA watershed and multi-functional workshop and Appendix 3 for the attendees at the Southwest Diagnostic Farm days (July 4, 2011).

2.1 NVCA Watershed

The NVCA watershed, located in south-central Ontario, is approximately 3700 km^2. The watershed extends south from Georgian Bay to the Oak Ridges Moraine and Dundalk till plain/Niagara Escarpment in the west to the Simcoe Uplands in the East (Fig. 1). It is located directly west of the Lake Simcoe watershed. The NVCA watershed includes many areas of high agricultural capability ranging from extensive potato and sod production in areas associated with the Tioga and Honeywood loams to carrot and onion production in the muck soils of the Cookstown Marsh area; notwithstanding large areas of cash crop productions. These typically fine grained soils can be subject to wind erosion particularly during periods when no cover crop is established on the field, e.g. late spring and early fall (pre-planting and post-harvest times).

Photo: April 16, 2012 sand storm, Horseshoe Valley Road. Photo courtesy of Andrew Barrie (OMAFRA).

The Lake Simcoe Protection Plan is focused on phosphorus (P) load reduction to improve water quality and the long-term health of the watershed. Out of the estimated 53 to 67 tonnes/annum (1998 to 2004 water years) of phosphorus entering Lake Simcoe, atmospheric deposition is believed to be responsible for 16 to 38 tonnes/annum (Ramkellawan et al., 2009). Preliminary research indicates the bulk of this atmospheric load to Lake Simcoe is due to windborne erosion

from agricultural soils to the north and west of the watershed (Lake Simcoe Science Advisory Committee, 2008); encompassing NVCA lands dominated by fine-grained Tioga loams and associated high value agriculture.

2.2 Previous work- phosphorus management

Lura Consulting (2010) developed research instruments using community based social marketing principles for the understanding of phosphorus issue with respect to agricultural practices in the Innisfil Creek subwatershed. This project focused on reduction of nutrient loading in watercourses from agricultural operations. Located directly west of the Lake Simcoe Basin, the Innisfill Creek subwatershed was chosen as a study site because it is dominated by agricultural land uses (78%) and there are serious water quality issues due to elevated phosphorus (P) concentrations in surface waters. Based on 2006 CANWET modelling, the primary source of P in the subwatershed is fertilizer applied to cropland (Greenland International Consulting, 2006). This area is also noted for extensive fine grain soils subject to wind-borne erosion. Through 3 focus group meetings in December, 2009 with the cash crop, potato, and equine sectors; a summary list of phosphorous Best Management Practices (P-BMPs) was developed and ranked according to impact and probability of adoption by the agricultural community. The top ranked BMPs identified for the cash crop and potato sectors included:

- Install (or maintain) wind breaks for erosion control
- Establish appropriate riparian buffer zones
- Use of cover crops after harvest
- Apply fertilizers to land at appropriate rate, time and place

It is noted that a key barrier to adoption of the wind break BMP was the inconvenience (e.g. few programs in place to support installation of windbreaks

3. Wind Break Characterization

3.1 Wind Break Types

Farm windbreaks have their origins in the mid-1400's when the Scottish Parliament urged the planting of tree belts to protect agricultural production (Brandle, 2004). Windbreaks, quite simply, are linear plantings of trees and shrubs designed to enhance crop production, protect people and livestock, and benefit soil and water conservation. In general, the following definitions are broadly applied:

- **Windbreaks** are a vegetative barrier that reduces the flow of wind and the associated negative impacts. They consist of one or more row of trees or shrubs in open field areas or upwind and adjacent to buildings.
- **Shelterbelts** are a vegetative barrier that reduces the flow of wind and the associated negative impacts. It has at least six rows of trees or shrubs in open field areas or upwind and adjacent to buildings.
- **Timberbelts** consist of multiple rows of trees planted for both production of tree crops and environmental benefits, e.g. wind protection, soil conservation, and wildlife habitat.

This is further augmented by:

- **Fencerow** refers to the uncultivated land on each side of a fence.
- **Hedgerows** refer to tree, shrubs, or hedges in a row running along the road or separating two properties.

The porosity, tree species, and tree height of the windbreak are the main factors in determining how effective the windbreak will be. A well designed windbreak will protect an areas downwind of approximate 10 to 15 times the height of the windbreak. Thus, a 30 foot tall windbreak will protect and area 300 to 450 feet downwind. It is important to understand the relationship of windbreaks and how porosity (and hence the choice of plants and numbers of rows) relates to function. Porosity is usually a visual estimate of how much plant material blocks the sight of sky within the

windbreak zone. Or simply stated, it is the amount of air space in a cross sectional view of a windbreak that allows wind to move through the barrier. For example 70% porosity means that about 70% of 'sky space' is seen through the windbreak, thus leaving 30% of the visual plain space being obstructed by tree branches, trunks or leaves. In general, the performance objective from a field protection perspective is to maintain preferred 40% - 50% summer porosity and 70% winter porosity homogeneously up through the vegetated column, with the added benefit when using multiple species of increasing functional bio-diversity. There are many variations of windbreaks, including:

Field Windbreaks: Many windbreaks are deployed in, around, or otherwise at the edges of fields. They usually consist of a single-row or equivalent of plantings with 40% to 50% summer porosity and 70% winter porosity; however, may have more than one row of plantings (e.g. field shelterbelt).

Farmstead windbreaks: Located around the farmstead area to protect buildings or livestock yards as well as laneways, etc. Porosity of these windbreaks should be 50% in both summer and winter. Around farm buildings such windbreaks can reduce building heating costs by up to 25%. They also reduce animal stress, generally improve animal welfare, and function for odour control. In special circumstances to disperse odours associated with hog operations, the porosity may be decreased to 40% to create wind turbulence above ground on the leaward side (Vézina, 2005).

Living snow fences: Living snow fences are considered natural windbreaks that trap snow as it blows across fields, piling it up before it reaches a transport artery. The ideal porosity to control drifting snow is 40 to 50% in winter. For effectiveness and economy, a single row of tall fences is preferable to multiple rows of shorter fences (Tabler, 1991). It is noted that living snow fences should be set back at least 35 times the height of the windbreak from the road shoulder (Tabler, 1991).

Willow biomass windbreaks: These are defined as short rotation biomass plantings, usually fast-growing shrub or hyrbid willow, which can be harvested in three year rotations. The biobalers can be baled using 'bio-harvesters' or chipped for livestock litter, landscape mulch or heating fuel (See http://www.irbv.umontreal.ca/chercheurs/michel-labrecque?lang=en and www.agroenergie.ca). This type of windbreak can also be useful for controlling drifting snow and accumulating snow across fields, thereby functioning as a living snow hedge.

3.2 Windbreak profiles

Broadly speaking, multi-functionality is realized by considering various types of plantings or functional elements in addition to those found in conventional windbreaks. Typically the 'core' or requisite elements are coniferous trees and/or deciduous trees, usually in single or double rows.

Optional or additional rows of coniferous and/or deciduous trees can be added either upwind or downwind of the core plantings, particularly when protection of farm buildings, farm lanes, etc is desired. Multi-functionality is further achieved when either the core or the additional rows consist of harvestable coniferous or deciduous trees, small or large naturalization or edible shrubs, dwarf fruit trees, cane fruits, perennial vegetables, and ground covers including vegetable row crops. Perennial vegetables are woody or non-woody edible plants such as rhubarb, sorrels, asparagus, various perennial herbs, etc. Other physical elements can also be considered for use to further diversify use of the windbreak, such as bee hives or other livestock service structures such as watering stations or weather protection shelters for on-farm value added benefit. It is noted that windbreaks may need to be fenced to keep out livestock in order to protect plantings from damage. Altogether these elements can be considered as various tools in the multi-functional windbreaks 'toolbox' for design to suit one's specific needs. See Fig. 3 for the generic designs referred to in this section. Please refer to Fig. 2 for the accompanying legend. Depending on the landowner's preference, windbreaks may require more than a single row to achieve greater degree of protection; here two or more rows may be effective.

When initially considering a windbreak design, the overall profile of windbreaks in cross-section can be conceptually considered a 'T', 'Block' or 'Dome' shape, based on species selection or placement in the row sequence (Fig. 3). Functional determinants in this case may include type of farm machinery (for getting close to the field edge), relative shade-tolerance of crops, desired shading of a laneway, or degree of multi-functionality desired; such as growing shrubs for fruit production, pollinator, or other wildlife habitat.

The type and shape of farm machinery involves considering the height or mass of the machine that needs to extend beyond the field edge, or workable area. For example, a machine that occupies a space 3' above the ground and 4' beyond the workable field edge will require at least this space to be clear of tree branches. This area may need to be pruned while the trees are young to achieve a desired shape. Otherwise excessive branch pruning would be required to locate the tree closer to the workable field edge. In this case a 'T' shaped windbreak in profile would be more suitable than a 'Block' or 'Dome' shaped windbreak. Depending on the farmer these considerations may or may not be as important as other design preferences such as having hardy shrub species in upwind locations or pollinator plants in protected leeward locations.

3.3 Plant Species

Plant species selection consistent with similar previous windbreak installation is determined in consultation with land owners and according to on-site soil types and other environmental conditions. Information on plant species preferred soil types is commonly available; the reader is referred to http://www.wbvecan.ca/anglais/document.html; Click on 'Selection of Plants' and then 'Course Notes' and Agriculture and Agri-Food Canada et al. (2008). For specific Ontario conditions, consult the BMP book "Establishing Tree Cover" (AAFC et al., 2008).

Soil types matched to some commonly-used windbreak species include:

- Soil type- **All**: Silver maple, Black willow, Ninbark, Red-osier dogwood, White cedar
- Soil type- **Loamy to sandy**: Cotttonwood, Red oak, Elderberry, Tamarack, White spruce, White pine
- Soil type- **Loam to clay loam**: Black walnut, White pine,
- Soil condition- **Moist**: Alternate-leaved dogwood, Nannyberry
- Soil condition- **Fertile**: Highbush cranberry

3.4 Generic Design

Beyond shape in cross-section, several other factors need to be considered when choosing a multi-functional windbreak. Building on the state of the art development of similar windbreaks in Ontario and Québec by Vézina et al. (2007), various typical generic designs for windbreaks are shown in graphic format with text descriptions (Fig. 2- discussion key and Figs. 4-6). The graphic depictions assume prevailing winds blow from left to right; and field edges, edges of pastures, or other open areas are at the edge of the windbreak width indicator lines. Note: the figures are organized by function and numbers of rows of plantings. Fig. 4 is for field protection using a single row of plantings, Fig. 5 is for field protection using double or multiple rows, and Fig. 6 is for farmstead and roadway protection using single, double or multiple rows of plantings. These generic designs are intended to form the basis for discussion with farmers and farming groups for implementation of site-specific designs.

Generic windbreak designs for this project have been developed principally for the reduction of wind-associated soil erosion which has a target of 40% - 50% summer porosity and 70% winter porosity (Figs. 4 and 5).

3.4.1 Single Row Multi-functional Windbreaks

The typical 'core' or requisite elements of windbreaks are coniferous trees and/or deciduous trees (Figs. 4.1 and 4.2). Variations on the single row design may also include single or double alternate plantings of deciduous trees with coniferous trees (Figs. 4.3 and 4.4). Double alternate spacings (Fig. 4.4) have the advantage of permitting thinning (and harvesting) every second tree if needed or as desired over time, in as little as 15 - 20 years using poplars or as much as 60+ years using sugar maple or oaks; resulting in a single alternate spacing configuration.

Further variations on single row planting include alternating deciduous trees with single or multiple deciduous shrubs (Fig. 4.5), or increasing the alternation of conifers with deciduous trees along a row to three, or four, or five, or more down a mostly deciduous row. This may permit subtle adjustments in seasonal performance including some additional trapping of snow in a narrower accumulation area or sustained microclimates in shoulder seasons. This also allows for some biodiversity.

These multiple row concepts can also be used for farmstead and roadway protection (e.g. Figs. 6.1 and 6.2).

In-row spacings (spacing between plants down the row) may be reduced to enhance wind erosion control; trees may be reduced to 3.0m or even 2.0m on centre and certain species such as willows (*Salix* spp.) may be reduced to 0.5m on centre.

Single rows of multi-stemmed lower-growing shrubs, taller shrubs or small trees such as willow (*Salix* spp), gray dogwood (*Cornus racemosa*) or shrub hazels (e.g. *Hamamelis virginiana*) may also be desirable for reducing wind erosion since they do not consume as much space as trees, and have a homogeneous stem density near ground level (Fig. 4.1). Particularly fast-growing willow hybrids or species such as Beeked willow (*Salix bebbiana*), when planted at the recommended spacings of 0.50 m on centre down one row or preferably as two rows offset 0.50 m apart (Figs. 4.6 and 5.3), will produce a 'wall' of permeable vegetation. Moreover, the effectiveness of this approach will be greatest when multiple windbreaks are grown across a field or open erosion-prone area offset every 10h to 20h, with 15h being a suitable average (Fig. 6.3) where 'h' refers to mature height of the windbreak. It is noted that raising canopies of taller trees or shrubs can be done in single row windbreaks.

3.4.2 Multiple Row Multi-functional Windbreaks

Multiple rows can be planted in a wider windbreak when space limitation is less of a concern, or when bio-diversity for pollination, aesthetics, biomass or other income diversification is desired. Multiple rows can be planted to function as a single field protection row, and thereby maintain the preferred 40% - 50% summer porosity and 70% winter porosity from ground level up through the windbreak column. This is achieved by raising the canopy of taller plants so that shorter plants can be grown alongside the taller plants (Figs 5.1 and 5.2).

Raising canopies of taller plants (by limbing lower branches) may be made by raising one canopy in the profile, such as those of taller trees for lower-growing shrubs (Fig 5.1). Or, as outlined in Fig. 5.2, raising both canopies of the taller tree and taller shrub can permit a third row of the shortest plants to be established. These plants can be perennial or annual, or can have a management regime that benefits from annual or multi-year trimming or mowing (Agriculture and Agri-Food Canada et al., 2004).

Similar to a single row windbreak, the in-row spacings (spacing between plants down the row) may be reduced in order to enhance wind erosion control; trees may be reduced to 3.0m or even 2.0m on centre and willows (*Salix* spp.) may be reduced to 0.5m on centre for multiple row windbreaks.

It is important to note that either single row or multiple row designs may consist of species that provide harvestable crops such as willow bio-mass, berries and other fruits, firewood or building materials such as fence posts, saw logs or veneer logs, seasonal products such as Christmas decorations or other specialty bio-materials. Where harvesting results in complete ground-level coppicing and regrowth in a medium-term rotation, such as 3-year rotations for willow, or a longer rotation involving eventual removal of a tree, spacing between windbreaks may be adjusted ensure both continuous harvesting and continuous field-protection.

In multiple row windbreaks where berry or fruit harvesting is desirable, or within the overall profile where special row crops are cultivated, row spacing may need to be widened to permit access for harvesting machines. For example mechanical berry harvesters typically need a minimum of 3.5 m between rows and as much as 6.2 m between rows for larger plants such as Saskatoon berries, where hand-picking typically only requires 2.7 m between rows (Fig. 5.2).

It is important to note that in the case of edible species, the landowner is responsible for maintenance, harvest, marketing or other sales activity for either fresh or value-added products. This may be done independently or in partnership with other specialized grower, value-added or marketing groups or support business(es) at the landowners discretion. This is not unlike the responsibility that landowners have for harvesting wood for biomass or saw logs. Edibles however can usually be harvested every year. Very similarly to their other field crops, protocols need to be exercised in all respects concerning food safety and security, and food quality.

4. Demonstration Site Designs

Demonstration sites provide opportunities to the larger agricultural-rural community to gain firsthand experience with the environmental and economic benefits of windbreaks in south Simcoe County. Through these demonstration sites, this community is able to witness the diversity of roles that wind breaks play in rural environments, as well as various designs that can be utilized.

Demonstration sites were targeted in key areas subject to known wind-borne, agricultural-based soil erosion in the NVCA watershed; centering on the Tioga loams (e.g. the Beeton-Alliston-Angus corridor; Fig .1). Other targeted areas of interest included the Anten Mills-Midhurst-Minesing area and the Cookstown Marsh area; given the collectively proximity to the Lake Simcoe basin and the predominant north-west to west prevailing wind directions. Within the targeted areas, four demonstration sites were selected with accommodating farmers to potentially illustrate multifunctional wind breaks and windbreaks on their respective properties.

The landowner at each site was visited by the project consultant, designs were agreed upon, and planting proposals were rendered. Each planting proposal provides an overview of proposed windbreak locations, descriptions for each windbreak, and a summary plant list for that project. The multi-functional windbreak design options are based on the generic designs (Fig. 3) which can then be further refined in terms of species selection according to the interests and needs of the landowner. Planting proposals may also contain specific instructions for current or future years, such as vegetation removal to permit establishment of new windbreaks, or locations of ‘Test Areas’ that are intended to allow the farmer to compare such variables as crop yields and plant health as well as disease outbreaks between locations that are known to benefit from windbreaks, or not.

Following rendering of the designs to the landowner, NVCA staff revised the design based on available materials, supplies, costs, and landowner willingness. It is noted that the NVCA site plans contain the same general information as the consultant designs (e.g. trees to be planted, planting site information, site preparation notes, planting, air photo, etc). Following, a landowner agreement was entered between the NVCA and the landowner.

The design plans drafted by the Consultant are provided in Figs. 7-10. The revised NVCA site plans, which correspond to the actual demonstration site plantings are located in Figs.11-14. Both are provided to demonstrate the variance between the concepts of multifunctional wind break designs (C. Brad Peterson Environmental Management and Landscape Architecture) and the resulting actual plantings agreed to by the farmer and available planting stock (NVCA designs).

Each of the Case Study sites is reviewed and any special qualities that make the Case Study unique are mentioned. For reasons of privacy and confidentiality in this report, addresses of sites and identity of landowners are confidential. In some case studies, the NVCA was not able to plant the recommended species for a number of reasons, one being availability of species.

Case Study 1 is a 100-acre potato farm with additional mixed cropping (Fig. 7). Unique to this demonstration site is Windbreak A on the west side of a winter wind-blown and snow-drifted County Road. This is based on the generic design Fig. 4.1. Windbreak C contains only shrubs and terminates before reaching the east property line to permit views to the south-east. This is a variation of Fig. 4.1 where only shrubs are grown. A similar break in Windbreak B permits some view to the west. Windbreak E, based on Fig. 6.2 design with elements of Fig. 5.1 has a row of dwarf sour cherries for fresh on-farming eating and perhaps surplus market.

It is noted that this case study did not result in a demonstration site planting due to the inability for timely site preparation.

Case Study 2 is a 200-acre potato farm with additional mixed cropping (Fig. 8). Unique to this proposed study design is Windbreak A, based on Fig. 4.4, located on the east side of a winter wind-blown and snow-drifted County Road. Windbreak C is similar, oriented 90 degrees to an older field row to be removed. This will open up a larger field area to cultivation and protect higher elevation land as well as fields downwind. Windbreak D contains mostly fruiting shrubs but also has five sugar maples to mark a dogleg in the property line. Windbreak E is a buffer strip comprising mostly of fruiting shrubs, or may be substituted with rows of fast-growing shrub or hybrid willow. Windbreak F is similar to Windbreak E. Windbreak G involves interplanting deciduous trees in an existing hedgerow in order to infill tree gaps to produce a consistent porosity along the vegetated row.

The revised NVCA site plan for this property consisted of Windbreak A and B being pursued (Fig. 11). Windbreak A consisted of single row of Colorado Blue Spruce (compared to the originally single double alternate row of larch with red oak. The planted Windbreak B consisted of white spruce and nannyberry, single spaced. The variation from design to planting was due to barriers of multifunctional windbreak concepts by the farmers.

It is noted that another demonstration site was established by the same landowner of the Case Study 2 in another farm which consists of single row plant of White Spruce and European Larch, referred to Case Study 2a (Fig. 12).

Case Study 3 is a 100-acre sod farm (Fig. 9). Based on the proposed design, Windbreak A is similar to that shown in Fig. 4.4 where every other conifer and deciduous tree is removed within 20 years. It is noted that the thinning will temporarily increase porosity. Windbreaks B and C are similar in this regard.

The design and site plans for this demonstration site are quite similar albeit with a few species substitutions (Fig. 13).

Airphoto of case study 3

Case Study 4 is a 73-acre potato distribution centre with working fields (Fig. 10). Windbreak A, most resembling Fig. 4.3, is located directly beside an existing overgrown hedgerow that will be cut back. Since the trees in this hedgerow are short-lived poplars and Manitoba

maples, the new Windbreak A will provide proper long-term field protection. Windbreak B similar to Fig. 4.4 is a new hedge for protecting a field from the north winds. Windbreak C similar to Fig. 4.2 is located beside an existing municipal and gas service (formerly rail) corridor. Windbreaks D, E and F similar to Figs. 6.1 and 6.2 are building protection hedges.

The design and site plans for this demonstration site are quite similar albeit with a few species substitutions (Fig. 14).

A review of the types of windbreaks used in the above Case Studies shows that the full range of windbreak types shown in Fig. 3 can be used in adaptable situations involving field protection, building and road protection, and buffer strips. Introduction of harvestable fruiting shrubs is a novel introduction in Case Studies 1 and 2; however, noted, not pursued in the actual site plantings.

Photo of a single row windbreak, Case Study 4

5. Economic Model

Windbreaks do take cropland out of production. However, economic return on an investment in a windbreak can play an important role in a successful farming business. It is often difficult for farmers to envision this reality. Realizing a return within a given number of years, especially in the near term, is therefore an extremely important factor in their decision making whether to plant them. For example, the return on investment for a drainage system is usually more than 12% a year with the usual payback period is 7 to 10 years. The following economic model is an important tool that will help farmers with ease of decision making.

In general, economic returns through increased crop production over time usually far outweigh the costs of planting and maintaining a windbreak; although maintenance is required to maintain effectiveness. Anything further that can be harvested and sold or has other market value from the windbreak itself reduces the payback period even more. Typically the amount of crop yield decrease in the zone directly adjacent to the windbreak is more than offset by yield increases within the remaining total field area positively affected by the windbreak. These and other economic / environmental aspects of windbreaks have been well documented (Kort, 1988).

An economic simulation tool was used to determine fiscal outcomes for planting individual windbreaks in the some of the Case Study sites in the study area. The tool, based on a Microsoft Excel spreadsheet format, is named 'Simulation tool to assess the economic impacts of agroforestry practices'. The simulation tool can be found online at http://www.wbvecan.ca/anglais/coutspdf.html. It was developed under supervision of André Vézina at Biopterre Centre de development des bioproducts in Québec with assistance from Agriculture, Pêcheries et Alimentation Québec and Agriculture and Agri-Food Canada.

According to its own description, the model can determine the discounted margin between the savings and income generated by the windbreak and the costs associated with establishing and maintaining the windbreak. The questionnaire portion of the tool requires inputs for the number of rows of plantings, types of species, spacings, how often dead trees are replaced, frequency of mowing, pruning and protection management, hedge length, rotations of land otherwise removed from cultivation, annual building heating costs, cost of snow removal, types of markets of harvested wood, yields, type and market values of fruit, how much yields have increased and value of carbon credits per ton, as applicable. A summary table is then provided that indicates the number of years to payback, how much carbon has been sequestered, and over time intervals of

initially 5 years to up to 40 years, the economic margin, discounted margin and cumulative discounted margin, as well as income and expense graphs.

It is worthy to note that the payback period indicated in the economic model does not consider land value, only the value of crops. Payback to society for the broader social benefits of windbreaks on farms are considered in some sense where a price for carbon sequestration is allowed to offset expenses and a price is allowed for the value protection of soil from erosion. Many jurisdictions do not yet recognize such broader social values, and so cannot be included in the present iterations of the model.

When using the tool, it is important to recognize that only one windbreak can be modeled at a time but that individual iterations can be saved for future reference. The present model provides simulations for up to 40 years, hence economic returns beyond this time horizon, such as harvesting saw logs or veneer logs (including rotary cutting), for example in 60 or 80 years, will not be considered in the models' outcomes. In this case, one must add in the margins for additional harvest income over and above what the model shows. Also, there may be other types of harvesting, such as tree mast (nuts and pods) beginning in 12 or 15 years, or tree fruits beginning in 5 or 6 years that the present model does not consider, which should then be added in to income projections. Revisions to the present model are being considered to permit input of additional harvesting regimes over more flexible time frames.

5.1 Results of Running the Economic Model

The regional economic factors, where updated, reflect local conditions. The model is also illustrated herein, where it was run for all the generic designs in Fig. 3 in order to provide a generalized comparative economic evaluation between various types of windbreaks under the Economic Comparison heading. Results of one such iteration is provided in Fig 15.

Since this project introduces the concept of enhanced economic returns using more edible species than usual, comparisons are made between 'standard' windbreaks largely without these products, but not without income through wood harvesting (Figs. 4.1, 4.2, 4.3, 4.4, 4.6) and those with edible marketable products such as fruits, nuts and berries (Figs. 4.5, 5.1 and 5.2). Note that the payback periods are typically around 16 to 18 years for windbreaks that only consider wood harvesting, while payback periods are typically around 7 or 8 years (or about half that of those with just wood harvesting) when fruit harvesting is carried out. The differential is whether the farmer wishes to engage in the time needed to develop additional market structure for fruit sales, or wishes to diversify farm production along these lines including personal use of fruit consumption.

Note that the payback periods for farmstead and roadway protection windbreaks are also around 8 years. This is largely due to savings on building heating and snow removal costs (Figs 6.1, 6.2). It seems as though further reduction of payback period is not realized when fruit production is added in to this type of windbreak, most likely because it takes up to five years to initiate production of marketable fruit.

Fast-growing shrub or hybrid willow windbreaks require further market development in Southern Ontario, in order to develop a consumer base for willow biomass as a heating fuel, livestock litter, or landscape mulch. As noted above, windbreak also contributes to protection of natural areas, reduced soil erosion, and serves a number of multi-functions, such as building protection, road protection and natural areas protection at the same time.

Practitioners are encouraged to run the model to gain insight into their unique circumstances. The reader is referred to additional information on the topic of economics and windbreaks at Vézina et al. (2007).

5.2 Case Study Economic Evaluation

A specific component of each case study was evaluated using André Vézina's economic simulation model to determine the forecasted long term economic return of the windbreak.

Case study 2, Windbreak C: This windbreak consists of a new field protection hedge 693m in length. It is modelled to consist of a single double alternating red pine and red oak with 3.0m on centre spacing with half of red pine exchanged for larch and half of red oak for pin oak. It is designed to remove every other tree for biomass harvest in 20 – 40+ years.

The payback period for Windbreak C in Case Study 2 is 16 years which among other factors considers that some trees will be pruned for wood quality (lumber), rodent and deer tree protection is used, and some conifers and hardwoods are harvested for lumber. These factors are kept the same for the next case study but factors associated with farming are changed. The total carbon sequestered (ton CO_2 equivalent) after 40 years is 357.

Table 1: Economic evaluation of Windbreak C, case study 2.

Period	Improvements in incomes	Decreases in incomes	Margin (improvement-decreases)	Discounted margin	Cumulative discounted margin
0-5 years	0	-1095	-1095	-1066	-1066
5-10years	976	-884	91	82	-984
10-20 years	3781	-1181	2600	2212	1228
20-40 years	15265	-2363	12902	9368	10596

Economic evaluation- Case study 3, Windbreak C: This windbreak consists of a new field protection hedge 360m in length. The windbreak will consist of a single double alternate row 1 with Spruce then larch, then 1 hybrid poplar, then 1 sugar maple, all 2.0m on centre (o/c) spacing. Every other spruce and poplar for biomass harvest in 20 – 40+ years will be removed. It is noted that the removal of trees will result in the temporary increase of porosity.

The payback period in Case Study 3 is 19 years, a little longer than in Case Study 2. While the windbreak is still used for field protection, and maintenance and harvesting is similar as in Case Study 3, the slightly longer payback period results when planting trees 2.0m rather than 3.0m on centre, which costs more initially. The main driver to a longer payback period however is that the increase in crop yield is expected to be less in sod (2.5% Case Study 3) than in potatoes (5% Case Study 2). The total carbon sequestered (ton CO_2 equivalent) after 40 years is 277. It is noted that the values in the summary table are smaller overall in Case Study 3 than in Case Study 2 because the windbreak is shorter and protects less field area (693m length in Case Study 2 compared with 360m length in Case Study 3).

Table 2: Economic evaluation of Windbreak C, case study 3.

Period	Improvements in incomes	Decreases in incomes	Margin (improvement-decreases)	Discounted margin	Cumulative discounted margin
0-5 years	0	-738	-738	-719	-719
5-10years	479	-581	-102	-95	-814
10-20 years	1855	-657	1198	1019	205
20-40 years	7983	-1314	6669	4813	5018

Economic evaluation- Case study 4, Windbreak D: This windbreak consists of a building protection break situated next to drainage swale for a totalled length of 482m. The windbreak will consist of a single row norway spruce with 3.0m o/c. Spacing.

The total payback period is 10 years. The total carbon sequestered (ton CO_2 equivalent) after 40 years is 132. The payback period is reduced to 10 years because the windbreak is used to

protect buildings that have a high heating cost ($10,000/year). Moreover, it is expected that snow clearing costs will also be reduced based on 32 hours per year at $ 45/hr. The numbers in the table are likewise greater, reflecting the savings involved in controlling the large heating cost expense.

Table 3: Economic evaluation of Windbreak D, case study 4.

Period	Improvements in incomes	Decreases in incomes	Margin (improvement-decreases)	Discounted margin	Cumulative discounted margin
0-5 years	0	-424	-424	-413	-413
5-10years	720	-455	265	245	-168
10-20 years	5380	-1136	4244	3639	3470
20-40 years	25980	-3636	22343	16507	19977

6. Windbreak Maintenance

Windbreaks are a long-term valuable investment. In order to obtain maximum benefits from a windbreak, it must be properly managed throughout its lifetime. Establishing functional windbreaks requires an investment in money, time, and effort. They cannot simply be planted and left to grow for the remainder of their life. Regular monitoring and management is necessary to ensure they are adequately protected. Over time, proper maintenance can reduce overall management costs and increase the functionality and viability of the windbreak.

Maintenance includes any post-planting care such as weed control, pruning, and thinning. Standard maintenance practices for windbreaks are well covered and are summarized below (e.g. Brandle, 2004). Ongoing activities are particularly important when direct economic benefits such as fruit or other biomass harvest is anticipated. Multi-functionality can also include biomass harvest over extended periods where some plantings are removed or pruned to favour others. These include the generic designs involving alternate spacing where faster growing / shorter-lived trees (e.g. poplars) are removed after a 15-20 year time period which releases longer term trees (e.g. oaks or conifers). Similarly, pruning in order to raise canopies of deciduous plantings may be required to give more space for alternate plantings of smaller shrubs to flourish. Harvest of saw logs will also have an optimum timeline of 40 years or longer. Interim plantings within or beside the windbreak may need to occur at approximately 20-year intervals so that a continuous supply of biomass is assured along with other uninterrupted benefits of micro-climate and field protection or snow drifting control. All of these results are of economic benefit to the farmer.

Weed Control - Grasses and weeds compete with trees and shrubs of all ages for moisture, light, and nutrients. There are three basic methods for weed control: mulching, cultivation, and herbicides. Mulch serves to reduce weed competition, conserve moisture, and reduce soil temperature. Weed barrier fabric, a man-made polypropylene fabric, does an excellent job of controlling vegetation and conserving soil moisture. Suitable organic mulches include wood chips, old straw or hay, and well-leached, dried ensilage. Organic mulches should be applied 2 to 4 inches deep around individual tree. Weed control in the first three years after establishment is crucial. Within the first year, invading grasses and weeds can threaten a young windbreak. The reduction of heavy grass build-up around the plants reduces habitat for mice and voles.

Pruning – When young, multi-stemmed trees are pruned, a faster growing, single-stemmed tree develops. Forked or multi-stemmed trees are prone to wind damage. They also tend to put on less height growth. Select a dominant trunk and prune out forks and extra stems before they become two inches in diameter. Do not prune branches on older trees because it reduces the density and effectiveness of the windbreak. Coppicing at ground level is a useful management tool that may further result in unique or useful bio-materials such as straight poles or basketry materials. Even some shrub fruits such as sea buckthorn may be more easily harvested when

fruit is borne on straighter and more upright current year stems rather than on more spiny multiple year growth.

Thinning and releasing - If a windbreak shows signs of crowding remove some of the trees, either individual trees within a row or entire rows. Candidates for removal include diseased, dying, and low-vigour trees.

Renovation can be considered a more drastic form of maintenance. It becomes necessary to renovate as a windbreak ages or deteriorates due to poor maintenance or design. If possible, renovation should start early enough to allow any new planting to become effective before windbreak protection declines.

7. Future Applications and Additional Information

Much has been learned about windbreaks in Canada since they were first planted in Ontario and the prairies in the 1930's. Agriculture and Agri-Food Canada has an extensive resource base on Agroforestry Practices on line (http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1186590611493&lang=eng). An associated site by the USDA National Agroforestry Centre also contains a wealth of information (http://www.unl.edu/nac/agroforestrynotes.htm). There are also excellent refereed publications on quality and nature of windbreaks, one in particular by a leader in the field, J.R. Brandle (Brandle, 2004). A summary of publications is provided in Appendix 4.

It is worthy to note earlier publications on incorporation of trees into agricultural systems, where not only for windbreaks but as actual tree crops (Smith, 1953). This area of study has been further developed in terms of mimicking natural ecosystem structure and function, otherwise referred in permaculture literature as 'forest gardening' or 'mixed polycultures (Douglas and Hart, 1978). These systems lend themselves to all types of farming practices and exhibit a full range of multi-functions, many of which have already been noted.

Essentially, the more multifunctional one makes windbreaks, including planting multiple species in layers or in rows, the more they become linear mixed polycultures. Future applications in multifunctional windbreaks may then be design hybrids that cross the linear form of windbreaks with the functionality of diverse polycultures. Such systems, also referred to as eco-buffers, have been developed in the Netherlands and implemented in Alberta (See http://www.producer.com/2012/01/windbreaks-gain-new-purpose%E2%80%A9/)/. These systems are generally multi-rowed with as many as 12 or more rows. The multi-functional windbreaks in this study focus on adding biodiversity within rows often as different species of trees and shrubs. Although not explored in much detail, non-invasive groundcovers (e.g. under the windbreaks) can also play a role with such functions as soil erosion control, pollination, soil improvement, and beneficial insectary habitat.

NVCA and other conservation organizations are encouraged to continue to implement windbreaks in both rural farm and other settled landscapes to realize the great number of benefits to society, the economy and the environment they provide. Not only do windbreaks benefit farming operations directly from field protection and subsequent crop quality and yield improvement, they also protect soils and improve air quality and reduce carbon footprint in terms of heating costs and snow clearing. Other benefits include improved habitat, but also with opportunities to diversity farm income with an array of food and fiber products, as well as with improved aesthetics and recreation opportunities.

8. References

1. Agriculture and Agri-Food Canada, Ontario Federation of Agriculture, and Ontario Ministry of Agriculture, Food and Rural Affairs, 2008. Best Management Practices: Establishing Tree Cover.

2. Agriculture and Agri-Food Canada, Ontario Federation of Agriculture, and Ontario Ministry of Agriculture, Food and Rural Affairs, 2004. Best Management Practices: Buffer Strips. 141 pgs.

3. Brandle, J.R. 2004. Windbreaks in North American agricultural systems, Nebraska: Kluwer Academic Publishers.

4. Douglas, J. S. and Hart, R. 1978. Forest Farming: Towards a solution to problems of world hunger and conservation; Rodale Press, 228 pg.

5. Greenland International Consulting Ltd. 2006. Assimilative Capacity Studies CANWET™ Modeling Project Lake Simcoe and Nottawasaga River Basins. Collingwood: Greenland International Consulting Ltd.

6. Kort, J. 1988. Benefits of Windbreaks to field and Forage Crops. Agriculture, Ecosystems and Environment 22/23: 165-190

7. Lake Simcoe Science Advisory Committee. 2008. Lake Simcoe and its Watershed Report to The Minister of the Environment. Queen's Printer for Ontario: 116 pgs.

8. Lura Consulting. 2010. Developing a Research Instrument for uncovering Benefits and Barriers to phosphorus reduction management practices in the Agricultural Landscape of the Innisfil Creek Subwatershed; 90 pgs.

9. Ramkkellawan, J., Gharabaghi, B., and Winter, J.G. 2009. Application of Weather radar in estimation of bulk atmospheric deposition of total phosphorus over Lake Simcoe. Canadian Water Resources Journal; 34(1): 37-60.

10. Smith, J. R. 1953. Tree crops, a permanent agriculture. Devin Adair Co., NY.

11. Tabler, R.D. 1991. Snow Fence Guide. Strategic Highway Research Program, National Research Council; 76 pgs.

12. Vézina, A., 2005. Farmstead Windbreaks. See http://www.wbvecan.ca/anglais/index.html

13. Vézina, A., F. Lebel, and C. Rivert, 2007. Cost-Benefit Analysis of Farmstead Windbreaks. Published by Syndicat des producteurs de porcs de la Mauricie (SPPM).

Figures

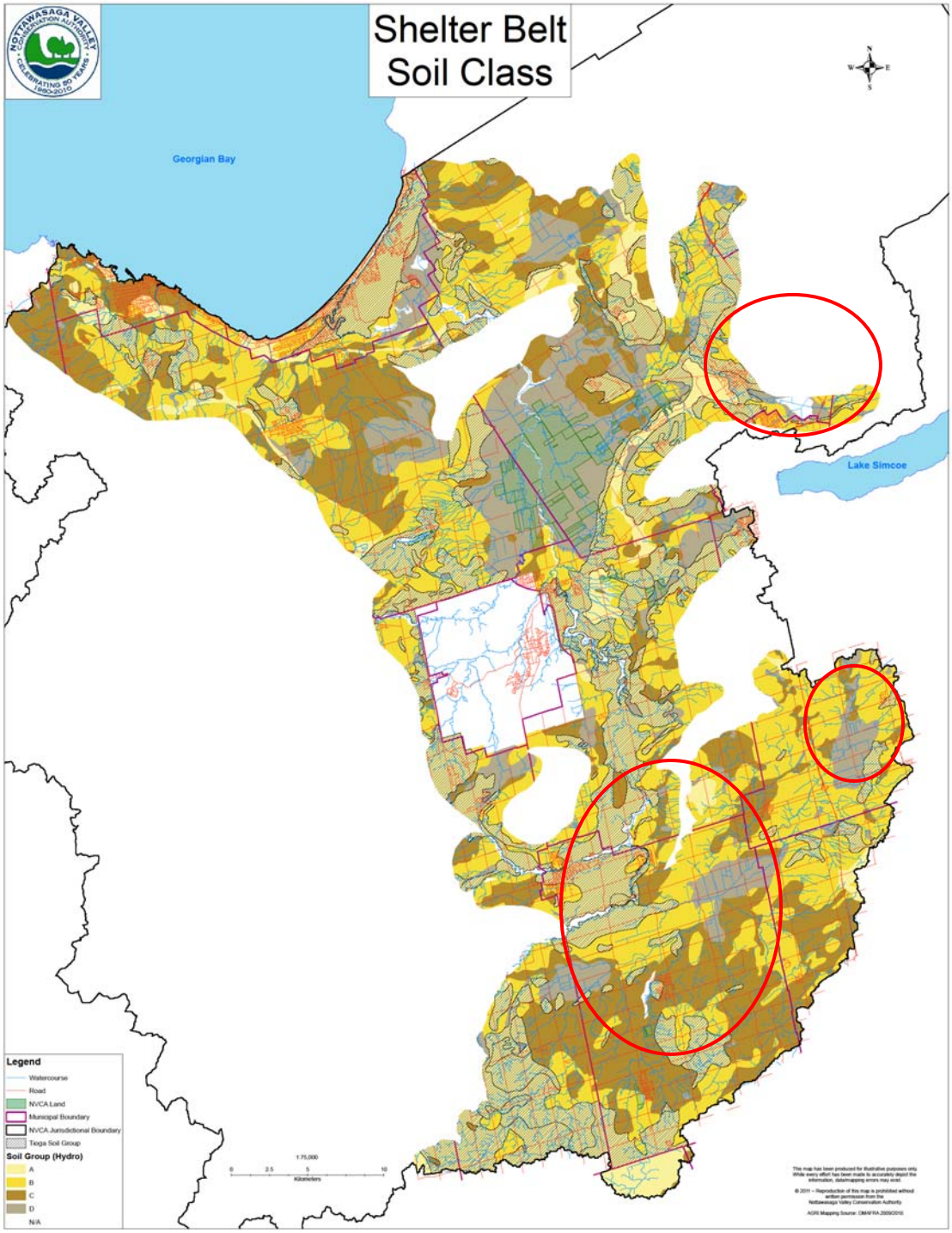


Figure 1: Hydrologic soil classification, Simcoe Lowlands, NVCA watershed. Soil type A and B are considered coarser grained (e.g. sandier) in comparison to soil type C and D. The highlighted areas are the demonstration site targeted areas.

Figure 2: Discussion key for Figures 3-5.

Description:	Number of rows and sequencing of species types down the row.
Purpose:	Primary use with secondary or auxiliary uses.
Working Width:	Amount of space (width) required
Mature Height:	Range of possible heights depending on species selected.
Spacing In-row:	Spacing in meters between plants down the row.
Harvestable Components and Timing:	Commodity type and frequency of harvest.
Maintenance Needs:	Additional maintenance practice above standard practice
Advantages:	Benefits of the windbreak above universal benefits of increased crop yields, improved snow deposition, and wind erosion control.
Disadvantages:	Any drawbacks relative to other generic designs.
Typical Species:	Typical species that can be selected for the Simcoe Tioga soil group. For a full range of species options see Table 4.
Economic Comparison:	Running of the economic model (Vézina et al.) was done to determine payback period based solely on the type of windbreak, keeping all other determining factors equal. This is meant for comparative evaluation only. Project-specific payback periods need to be determined on an individual basis by running the model for each windbreak. In this evaluation, determining factors kept equal include: • farms focused on potato production • hedge 400 m in length, planted in 4' wide plastic • poplars harvested after 20 years • hardwoods harvested after 40 years • all shrubs (unless noted otherwise) are fruit-baring • markets are in place for biomass (wood and willow biomass) and fruit sales • pruning for wood quality is carried out for deciduous trees • pruning for shape (fruit production) in carried out for shrubs • rodent and deer protection for deciduous trees, not for conifers • for farmstead and roadway protection (Table 3) annual heating costs are $5,000 • snow removal is carried out for entire length of hedge
Notes:	Other information pertaining to the design. Snow accumulation is important for retaining field spring moisture. Longer snow accumulation zones are based on 20h (20 x the mature height of the windbreak). Shorter zones are based on 10h. Moderate zones are based on 15h. Since nearly the same amount of snow may accumulate, snow depths can be deeper in shorter zones and less deep in longer zones.

Figure 3: Diagrams A, B and C Generic Profiles for Shelterbelt Design.

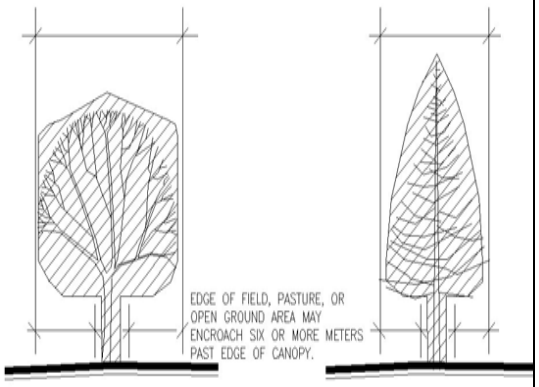
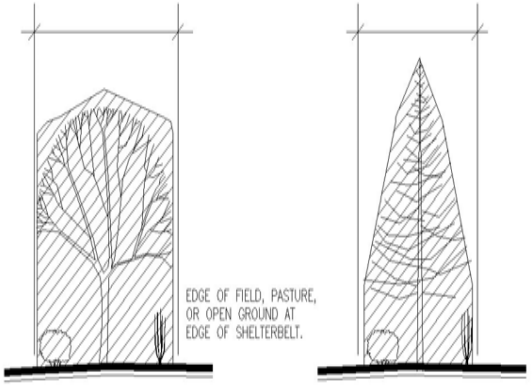
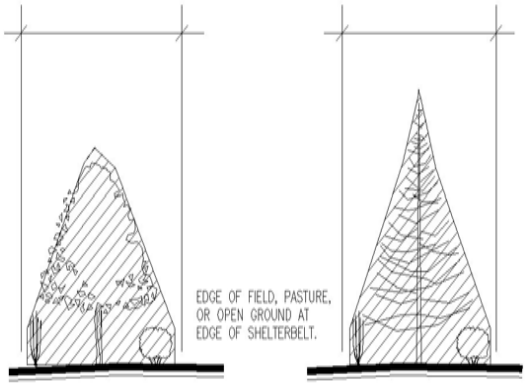
	Diagram A: Typical Elevation 'T' or Mushroom-shaped Windbreak	**Diagram B: Typical 'Block'-shaped Windbreak**	**Diagram C: Typical Dome or Pyramidal-shaped Windbreak**
			
Description	T' or Mushroom-shaped Windbreak	'Block'-shaped Windbreak	Dome or Pyramidal-shaped Windbreak
Purpose	Permits encroachment by farm machinery	Permits greater diversity, as underplantings	Permits greater light access to field edge
Working Width	6.0 - 8.0 m; may be only 3.0 - 4.0 m at ground	6.0 - 8.0 m	6.0 - 10.0 m or more
Mature Height	9.0 - 20 m	9.0 - 20 m	9.0 - 20 m
Maintenance Needs	Limbing of lower branches during establishment	Limbing of lower branches during establishment, underplantings care	Limbing of lower branches during establishment, underplantings care
Target Porosity	70% winter, 40% - 50% summer	70% winter, 40% - 50% summer	70% winter, 40% - 50% summer
Advantages	Allows more space for field operations	Allows for multi-functions: fruit production, etc	Allows for multi-functions: fruit production, etc.
Disadvantages	Pruning of branches during establishment	Takes some space, may require some pruning	Takes more space, may require some pruning
Typical Species	Oaks, maples, spruces, larch	Oaks, maples, spruces, larch, fruiting shrubs	Oaks, maples, spruces, larch, fruiting shrubs
Notes	Consistent with Figs. 5.1, 5.2, 5.3, 5.4, 5.5, 5.6 and 6.1, 6.2.	Consistent with Figs. 4.1, 4.2 where spacing between rows (less than or equal to 3.0 m) results in shrubs growing under the canopy.	Consistent with Figs. 4.1 and 4.2 where spacing between rows (greater than 3.0 m) results in shrubs growing at least partially outside the tree canopy.

Figure 4: NVCA Multi-function windbreaks generic designs- field protection, single row.

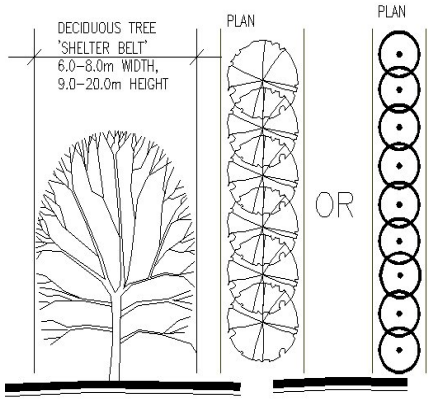
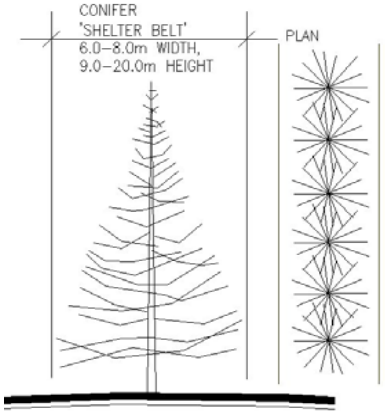
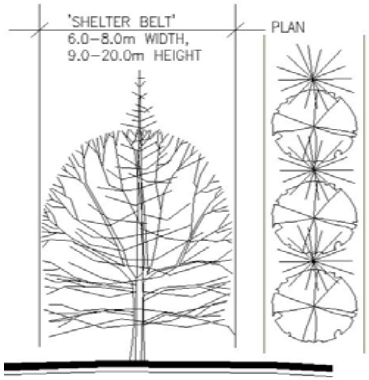
	Fig. 4.1 Single Row Deciduous	Fig. 4.2 Single Row Coniferous	Fig. 4.3 Single Row Alternate Deciduous / Coniferous
			
Description	Single Row Deciduous, one or more species	Single Row Coniferous, one or more species	Single Row Alternate Deciduous / Coniferous
Purpose	Field Protection, limited biomass harvest	Field Protection, limited biomass harvest	Field Protection, limited biomass harvest
Working Width	6.0 - 8.0 m	6.0 - 8.0 m	6.0 - 8.0 m
Mature Height	9.0 - 20 m	9.0 - 20 m	9.0 - 20 m
Spacing In-row	3.0 m o/c standard, up to 4.0 m o/c	3.0 - 4.0 m o/c	3.0 m o/c standard, up to 4.0 m o/c
Harvestable Components and Timing	Wood at maturity; 40 + years	Limited wood at maturity; 40 + years	Wood at maturity; 40 + years
Maintenance Needs	Standard for deciduous trees, some branch pruning	Standard for coniferous, some lower branch pruning	Standard for deciduous and coniferous trees
Target Porosity	70% winter, 40% - 50% summer	50% summer and winter	40% - 50% summer
Advantages	Lower cost, low maintenance, traps snow in greater distance	Low cost, low maintenance, traps snow in shorter distance	Lower cost, low maintenance, traps snow Moderate distance
Disadvantages	Potentially low diversity. Shorter plants affect less field area	Potentially low diversity	Marginally less than optimum 70% winter porosity
Typical Species	Oaks, maples for long term, poplars for quick short term	Pines, norway spruce or possibly larch	Oaks, maples for long term, poplars for quick short term and pines, norway spruce or possibly larch
Economic Comparison	Payback 18 years based on crop yield increases vs. implementation	Payback 16 years based on crop yield increases vs. implementation	Payback 17 years based on crop yield increases vs. implementation cost
Notes	Simple, narrow and inexpensive. Excellent porosity for field protection year round including longer snow accumulation zone. May also be based on replacing every 4th or 5th tree with a conifer, or single rows of deciduous shrubs, dwarf trees or hybrid willow for reduced Working Width of 3.0 - 4.0 m and Mature Height of 2.0 to 6.0m.	Simple, narrow and inexpensive. Excellent summer porosity for field protection with a shorter snow accumulation zone. Similar to Fig 5.1, larch has 70% winter porosity and offers some field protection in shoulder seasons	Simple, narrow and inexpensive. Good porosity for field protection year round including a moderate snow accumulation zone.

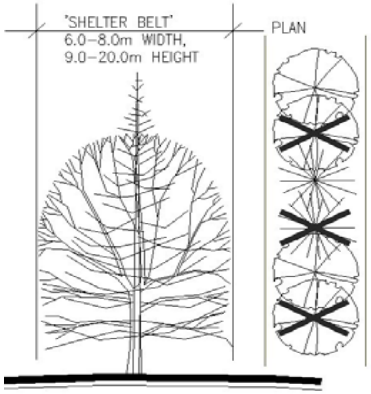
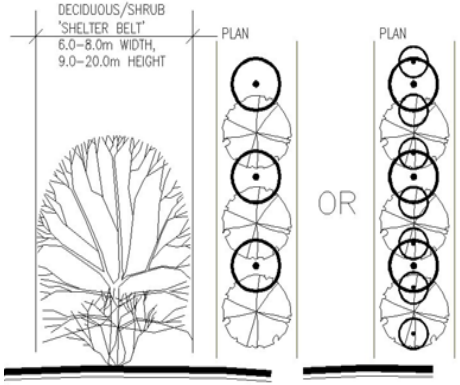
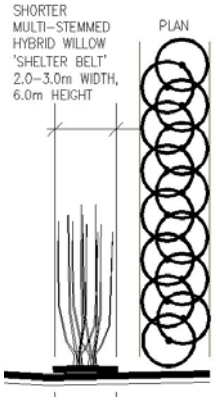
	Fig. 4.4 Single Row Double Alternate Deciduous / Coniferous	Fig. 4.5 Single Row Alternate Deciduous / Shrub	Fig. 4.6 Fast-growing Shrub or Hybrid Willow Shelterbelt
			
Description	Single Row Double Alternate Deciduous / Coniferous	Single Row Coniferous, one or more species	Shrub or Hybrid Willow Shelterbelt - Double rows, offset
Purpose	Field Protection, greater biomass harvest	Field Protection, limited biomass harvest	Field or farmstead protection, and biomass harvest
Working Width	6.0 - 8.0 m	6.0 - 8.0 m	2.0 - 3.0 m
Mature Height	9.0 - 20 m	9.0 - 20 m	6.0 m
Spacing In-row	2.0 m o/c standard, up to 3.0 m o/c	2.0 m o/c standard, up to 3.0 m o/c 1.5 m multiple shrubs	0.25m down alternate rows or 0.50m down each row
Harvestable Components and Timing	Wood at maturity; 20+ and 40 + years	Fruit in ~5 years, wood in 40 + years	willow biomass in 10 - 3-year rotations
Maintenance Needs	Standard for deciduous trees, some branch pruning	Shrub pruning for fruit production	Virtually none after establishment
Target Porosity	40% - 50% summer	70% winter, 40% - 50% summer	70% winter, 40% - 50% summer
Advantages	Lower cost, harvestable biomass in 20+ and 40+ years	Greater diversity, potential for fruit harvest, very good porosity	Produces biomass for fuel, fiber or livestock litter
Disadvantages	Marginally less than optimum 70% winter porosity	Potentially higher cost, production costs for fruit harvest	Requires bio-harvester and biomass market
Typical Species	Mix of hard and soft woods, eg, oak, poplar, spruce, larch	Oaks, maples, currants, gooseberries, haskap, etc.	Fast-growing shrub willow or hybrid willow
Economic Comparison	Payback 10 years based on crop yield increases, biomass harvest vs. implementation, maintenance costs	Payback 7 years based on crop yield increases, fruit harvest vs. implementation, maintenance costs	Payback varies based on crop yield increases, biomass harvest vs. implementation, maintenance costs
Notes	Simple, narrow and inexpensive to install. Good porosity for field protection year round including a moderate snow accumulation zone.	Simple, narrow and inexpensive. Excellent summer porosity for field protection with a shorter snow accumulation zone. Similar to Fig 4.1, larch has 70% winter porosity and offers some field protection in shoulder seasons . Over time, shading effects of the decidiuous trees will eliminate shrubs.	Excellent porosity and short 3-year harvest rotations for 30 years. This design may be used as field or farmstead and laneway protection windbreaks (payback periods may be reduced to 1 or 2 years), or used solely for biomass harvest.

Figure 5: NVCA Multi-functional windbreaks generic designs- field protection: double or multiple rows.

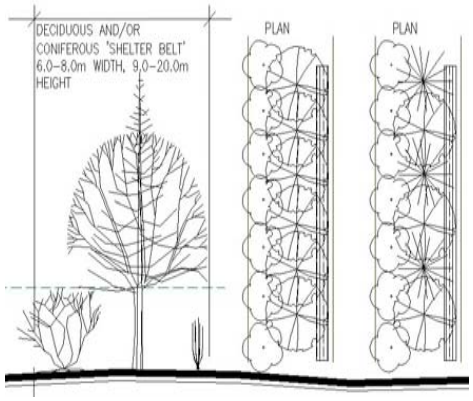
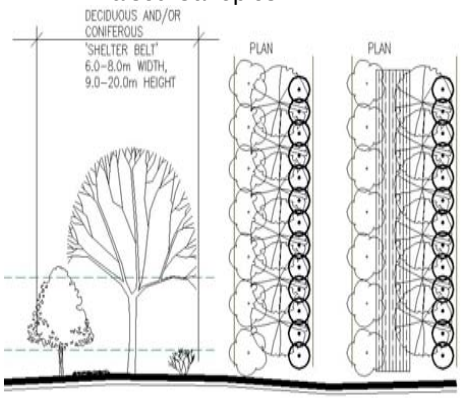
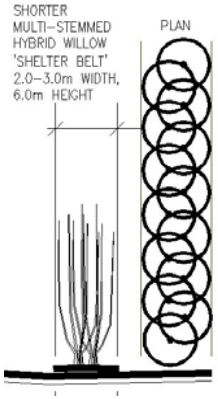
	Fig. 5.1 Double or Multiple Row Deciduous - One Raised Canopy	Fig. 5.2 Double or Multiple Row Deciduous - Two Raised Canopies	Fig. 5.3 Fast-growing Shrub or Hybrid Willow Shelterbelt
			
Description	Double or Multiple Row Deciduous - One Raised Canopy	Double or Multiple Row Deciduous - Two Raised Canopies	Shrub or Hybrid Willow Shelterbelt - Double rows, offset
Purpose	Field Protection, limited biomass harvest	Field Protection, limited biomass harvest	Field or farmstead protection, and biomass harvest
Working Width	6.0 - 8.0 m	6.0 - 8.0 m	2.0 - 3.0 m
Mature Height	9.0 - 20 m	9.0 - 20 m	6.0 m
Spacing In-row	3.0 m o/c standard, up to 4.0 m o/c 1.5 m - 2.0 m shrubs	3.0 - 4.0 m o/c	0.25m down alternate rows or 0.50m down each row
Harvestable Components and Timing	Fruit in ~5 years, wood in 40 + years	Limited wood at maturity; 40 + years	willow biomass in 10 - 3-year rotations
Maintenance Needs:	Shrub pruning for fruit production	Standard for coniferous, some lower branch pruning	Virtually none after establishment
Target Porosity	70% winter, 40% - 50% summer	70% winter, 40% - 50% summer	70% winter, 40% - 50% summer
Advantages	Greater diversity, potential for fruit harvest, v. good porosity	Greater diversity, potential for fruit harvest, v. good porosity	Produces biomass for fuel, fiber or livestock litter
Disadvantages	Higher maintenance (pruning) and production harvest costs	Higher maintenance (pruning) and production harvest costs	Requires bio-harvester and biomass market
Typical Species	Oaks, maples, currants, blackberries, raspberries, etc	Oaks, maples, currants, blackberries, raspberries, etc	Fast-growing shrub willow or hybrid willow
Economic Comparison	Payback 9 years based on crop yield increases, fruit harvest vs. implementation, maintenance costs	Payback 9 years based on crop yield increases, fruit harvest vs. implementation, maintenance costs	Payback varies based on crop yield increases, biomass harvest vs. implementation, maintenance costs
Notes	Excellent porosity for field protection year round including longer snow accumulation zone. Centre tree row can alternate with conifers or more shrubs, see 4.3 through 4.6 above. Naturalization shrubs can eliminate pruning costs. Between-row spacing 3.0m takes up more space than single row.	Excellent porosity for field protection year round including longer snow accumulation zone. See 5.1 Notes. Between-row spacing may be widened up to 6.2 m to permit row cultivation or mechanical berry harvesting.	Excellent porosity and short 3-year harvest rotations for 30 years. This design may be used as field or farmstead and laneway protection windbreaks (payback periods may be reduced to 1 or 2 years), or used solely for biomass harvest.

Figure 6: NVCA Multi-functional windbreaks generic designs: farmstead and roadway protection; single, double, or multiple row.

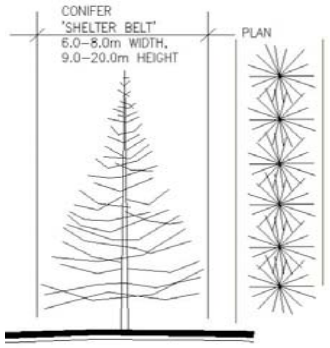
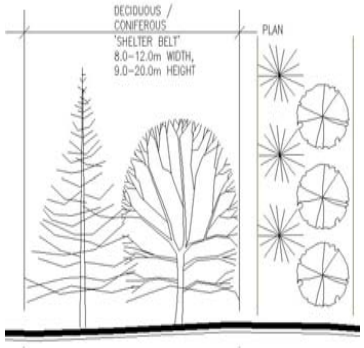
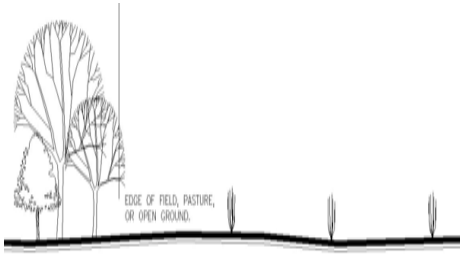
	Fig. 6.1 Single Row Coniferous	Fig. 6.2 Double Row Deciduous / Coniferous	Fig. 6.3 Successive Shelterbelts across Field for Whole-field Protection
			
Description	Single Row Coniferous	Double Row Deciduous / Coniferous	Successive Shelterbelts across entire Field
Purpose	Farmstead (building) or Roadway (laneway) Protection	Farmstead (building) or Roadway (laneway) Protection	Protection of entire field
Working Width	6.0 - 8.0 m	6.0 - 8.0 m	6.0 - 8.0 m
Mature Height	9.0 - 20 m	9.0 - 20 m	9.0 - 20 m
Spacing In-row	3.0 m o/c standard, up to 4.0 m o/c	4.0 m o/c down each row	3.0 m o/c standard, up to 4.0 m o/c
Harvestable Components and Timing	Wood at maturity in 40 + years	Wood at maturity; 40 + years	Wood at maturity in 40 + years
Maintenance Needs	Standard for coniferous, some lower branch pruning	Standard for deciduous and coniferous trees	Standard for deciduous and coniferous trees
Target Porosity	50% summer and winter	50% summer and winter	50% summer and winter
Advantages	Low cost, low maintenance, traps snow in shorter distance	Lower cost, traps snow in shorter distance	Each shelterbelt protects portions of field in 10h - 15h widths
Disadvantages	Potentially low diversity	Multiple rows take up additional space.	Individual shelterbelts may conflict with field operations
Typical Species	White spruce or Colorado spruce	See other shelterbelts in Fig. 4 and 5	See other shelterbelts in Fig. 4 and 5
Economic Comparison	Payback 8 years based on crop yield increases, savings on building heating and snow plowing vs. implementation cost	Payback 8 years same as 6.1	Paybacks based on types of shelterbelts above across the portions of fields for which they are effective
Notes	Similar to Fig. 4.2 above except uses more dense-growing conifer species. This design may also be based on fig 4.3 although winter porosity will be closer to 60% and snow accumulation zone slightly longer. Solid conifer rows should not be planted closer than 10m from buildings.	Double rows are usually all that is required, although multiple rows or either or both conifers and deciduous trees can be part of a much wider shelterbelt. Shrubs can also be included as an outside row on either with windward or leeward side.	Typical 10h - 15h distances are between 180m to 240m, so a 480m wide field may only need one shelterbelt in a central location. Impacts to field operations may be minimized by planting shelterbelts of less height, such as shrub rows or hybrid willow rows.

Figure 7: Case Study 1 demonstration site planting plan proposal, completed by C. Brad Peterson Environmental Management and Landscape Architecture.

Case Study 1
Shelterbelt Demonstration Site Planting Plan Proposal 2012

LANDOWNER INFORMATION: PROJECT INFORMATION:

Name: County:
Municipal Address: Township:
Mailing Address: Concession:
Postal Code: Lot:
Telephone: Email:

SITE DESCRIPTION:
Topography: gently sloping Soil: sandy Drainage: well
Ground Cover: field crops, grass verges, remnant woodland.

SITE PREPARATION DESCRIPTION: Landowner is responsible for site preparation in advance of planting, removing thick understorey in infill areas as desired, supply and installation of 4' ht. rodent / deer protection tubes or wraps on deciduous trees, and first year maintenance weed control and watering as needed to ensure survival. Where applicable clear and grub new hedge areas. Plow and disc or cultivate to flat planting bed. NVCA to lay 4' plastic in accordance with industry standards along all rows except D Infill, and sow white clover in intervening tilled areas.

ADDITIONAL INFORMATION: Planting dependant on spring weather conditions.

AGREEMENT: Standard Tree Planting Agreement to be provided by NVCA.

ORDER INFORMATION t.b.d.:

Species:	**Seedings 14"- 18"**	**Saplings 3'-4'**	**Potted/B&B:**
Red Pine	24		
White Spruce	6		
Maple, Red		147	
Maple, Sugar		168	
Red Oak		110	
Hazelnut		14	
Serviceberry		10	
Red-osier dogwood			30
Currant, Red			30
Currant, Black			25
Haskap			25
Dwarf sour Cherry			6

PLANTING DESCRIPTION:

A Road Snow Hedge 576m. **Single alternate row** 3 Red maple (144) followed by 1 Sugar maple [48] 3.0m o/c. Offset ~1.0m at PL. Check hydro lines.

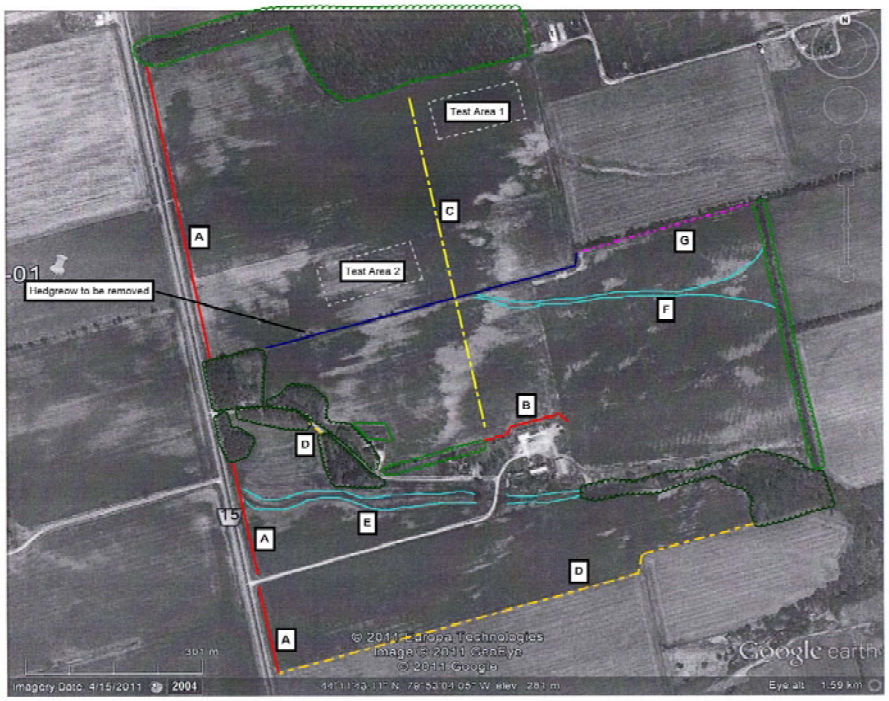
B New Field Protection Hedge 622m. **Single sugar maple** [90] **and red oak** [90] in groups of 3-7 individuals 3.0m o/c. Concentrate additional **red pine** (14) and **hazelnut** (14) at north end.

C Shrub Row 216m. **Single row** 2.0m o/c Red-osier dogwood (30), Red currant) (30), Black currant (25), Haskap (25). Plant in groups of 25 or 30.

D Ex. Hedgerow Infill 694m. Interplant as needed 4.0m o/c **sugar maple** (30)**, red oak** (20)**, red pine** (10) (west end), **serviceberry** (10) (west end). Plant and mulch as forestry planting. Remove thick understorey as needed.

E Building Protection Hedge 35m. Add **Red maple** (3) to existing White pine. One row **White spruce** (6)**, dwarf sour cherry** (6) 3.0m o/c**.** Min 6m from building.

Figure 8: Case Study 2 demonstration site planting plan, 2012, completed by C. Brad Peterson Environmental Management and Landscape Architecture**.**



Case Study 2
Shelterbelt Demonstration Site Planting Plan Proposal 2012

LANDOWNER INFORMATION: PROJECT INFORMATION:

Name: K County:
Municipal Address: Township:
Mailing Address: Concession:
Postal Code: Lot:
Telephone: Email:

SITE DESCRIPTION:
Topography: gently sloping Soil: sandy Drainage: well
Ground Cover: field crops, grass verges, cultural and remnant woodland.

SITE PREPARATION DESCRIPTION: Plow and disc or cultivate to flat planting bed. Lay 4' plastic in accordance with industry standards along all rows except G Infill. Sow white clover in intervening tilled areas.

ADDITIONAL INFORMATION:

AGREEMENT: I the undersigned landowner, in recognition of the Nottawasaga Valley Conservation Authority investment in this tree planting project, agree to the following for a 15 year-period starting when the trees are planted.

1. To take reasonable measures to protect the planting from fire, livestock, insects, disease, machinery, drought, and other harmful things.
2. To allow Nottawasaga Valley Conservation Authority staff and their agents onto my property to inspect the plantings.

At this time, the local county or region's tree cutting by-law remains discretionary for trees planted under this program. This status may change in future, without further notice.

Landowner Signature:
_____

Date: _____

NVCA Signing Officer:
_____

Date: _____

ORDER INFORMATION t.b.d.:

Species:	**Seedings 14"- 18"**	**Saplings 3'-4'**	**Potted/B&B:**
Eastern Cottonwood	1	1	1
White Spruce	1	1	1

PLANTING DESCRIPTION:

A Road Snow Hedge 982m. **Single double alternate row larch** [246] **with red oak** [123] and white oak (sub. Burr oak) [123], 2.0m o/c (492) offset 20.0m from PL or 2x – 4x most commonly-used machinery width or widest equipment width. Remove every other tree for biomass harvest in 20 – 40+ years.

B Building Protection Hedge 143m. **One alternate row poplar and burr oak** 3.0 o/c closest to building, offset ~10m from building. **One row wt. spruce or white cedar 3.0m o/c/.** Stagger plantings 3.0m between rows.

C New Field Protection Hedge 693m. **Single double alternate red pine** [116] **and red oak** [116] 3.0m o/c (232). Sub. half of red pine for larch, or half of red oak for pin oak. Remove every other tree for biomass harvest in 20 – 40+ years.

D Shrub Row 910m. **Single row fruiting shrubs** 1.5m o/c aronia (400), and black currant (200) sequences of 50 to 100. Interplant sugar maple 6.0-8.0m o/c (5) at PL dogleg. Include additional 33m row at north driveway; basswood 4.0m o/c (9). Sub. V. dentatum or Rosa rugosa 2.0m o/c and adjust quantity to [225 each] if these shrubs are used.

E Buffer Strip total 938m. **Single shrub rows** planted north and south of swale along bankfull-width line or to otherwise permit fruit harvest 2.0m o/c (row red-osier dogwood (110), Billard spirea (or red currant) (110), black currant (50), gooseberry (50), black elder (50), haskap (50), mulberry (50). Plant in groups of 50 or 55. Sub. **Hybrid willow** (3750) 0.50m o/c x 0.50m offset in 5' – 1 mil plastic.

F Buffer Strip total 850m. Single shrub rows planted north and south of swale along bankfull-width line 2.0m o/c (red-osier dogwood (100), nannyberry (100) Billard spirea (125), black elder (100). Plant groups of 50 or 75. Sub. **Hybrid willow** (3400) 0.50m o/c x 0.50m offset in 5' – 1 mil plastic.

G Ex. Hedgerow Infill 332m. **Interplant as needed 4.0m o/c sugar maple (15), basswood (5).** Plant and mulch as forestry planting. Remove thick understorey as needed.

Figure 9: Case Study 3 demonstration site planting plan, 2012, completed by C. Brad Peterson Environmental Management and Landscape Architecture.

Case Study 3
Shelterbelt Demonstration Site Planting Plan Proposal 2012

LANDOWNER INFORMATION: PROJECT INFORMATION:

Name: County:
Municipal Address: Township:
Mailing Address: Concession:
Postal Code: Lot:
Telephone: Email:

SITE DESCRIPTION:
Topography: gently sloping Soil: sandy Drainage: well
Ground Cover: sod crop, grass verges, remnant woodland.

SITE PREPARATION DESCRIPTION: Landowner is responsible for site preparation in advance of planting, removing thick understorey in infill areas, supply and installation of 4' ht. rodent / deer protection tubes or wraps on deciduous trees, and first year maintenance weed control and watering as needed to ensure survival. Where applicable clear and grub new hedge areas. Plow and disc or cultivate to flat planting bed. NVCA to lay 4' plastic in accordance with industry standards along all rows except B Infill, and sow white clover in intervening tilled areas.

AGREEMENT: Standard Tree Planting Agreement to be provided by NVCA.

ADDITIONAL INFORMATION: Planting dependent on spring weather conditions.

ORDER INFORMATION t.b.d.:

Species:	**Seedings 14"- 18"**	**Saplings 3'-4'**	**Potted/B&B:**
White Spruce	77		
Larch	77		
Eastern Cottonwood or Hybrid poplar		78	
Burr Oak		19	
Red Oak		14	
Sugar Maple		45	

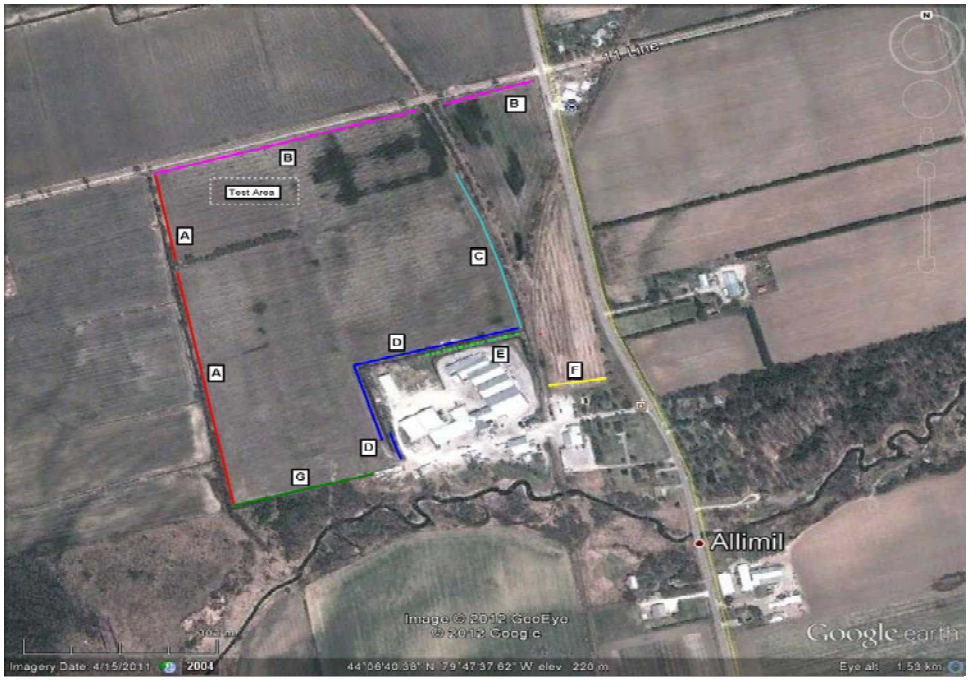
PLANTING DESCRIPTION:

A New Field Protection Hedge 145m. **Single double alternate row 1 wt. Spruce** [18], **then 1 larch** [18]**, then 1 hybrid poplar** [19], **then 1 burr oak** [19], all 2.0m o/c. Remove every other spruce and poplar for biomass harvest in 20 – 40+ years.

B Infill Existing Wooded and Verge line, 20m + 20m + 70m = 110m. Infill between existing large and small trees as needed. **Single double alternate row 1 wt. Spruce** [14]**, then 1 larch** [14], **then 1 hybrid poplar** [14]**, then 1 red oak** [14], all 2.0m o/c. Remove every other spruce and poplar for biomass harvest in 20 – 40+ years.

C New Field Protection Hedge 360m. **Single double alternate row 1 wt. Spruce** [45]**, then 1 larch** [45], **then 1 hybrid poplar** [45]**, then 1 sugar maple** [45], all 2.0m o/c. Remove every other spruce and poplar for biomass harvest in 20 – 40+ years.

Figure 10: Case Study 4 demonstration site planting plan, 2012, completed by C. Brad Peterson Environmental Management and Landscape Architecture.



Case Study 4
Shelterbelt Demonstration Site Planting Plan Proposal 2012

LANDOWNER INFORMATION:
Name:
Municipal Address:
Mailing Address:
Postal Code:
Telephone:
Email:

PROJECT INFORMATION:
County:
Township:
Concession: Lot:

SITE DESCRIPTION:
Topography: gently sloping Soil: sandy Drainage: well
Ground Cover: field crops, potato, grass verges, remnant woodland.

SITE PREPARATION DESCRIPTION: Landowner is responsible for site preparation in advance of planting, removing thick understorey in infill areas, supply and installation of 4' ht. rodent / deer protection tubes or wraps on deciduous trees, and first year maintenance weed control and watering as needed to ensure survival. Where applicable clear and grub new hedge areas. Plow and disc or cultivate to flat planting bed. NVCA to lay 4' plastic in accordance with industry standards along all rows except E Infill, and sow white clover in intervening tilled areas.

ADDITIONAL INFORMATION: Planting dependant on spring weather conditions.

AGREEMENT: Standard Tree Planting Agreement to be provided by NVCA.

ORDER INFORMATION t.b.d.: Substitutions may be made by NVCA.

Species:	Seedings 14"- 18"	Saplings 3'-4'	Potted/B&B:
Norway Spruce	397		
White Spruce	189		
Red Pine	108		
Basswood		10	
Oak, Burr		108	
Oak, Red		73	
Maple, Sugar		10	
Poplar		73	

PLANTING DESCRIPTION:

A Field Protection Hedge located next to existing hedgerow 650m. **Single alternate row red pine** [108] and **Burr Oak** [108] 3.0m o/c.

B New Field Protection Hedge 440m. west of r.o.w. plus 145m east of r.o.w.= total 585m. **Single double alternate white spruce** [73] **and Norway spruce** [73] with **hybrid poplar** [73] and **red oak** [73] 2.0m o/c). Remove every other tree (spruce and poplar) for biomass harvest as needed in 20 – 40+ years.

C Field and Road Protection Hedge next to r.o.w. 490m. **Single row Norway spruce** [163] 3.0m o/c

D Building Protection Hedge next to drainage swale 280m north of swale plus 137m west along 'outside' of swale, plus 65m on 'inside' of swale = 482m. Single row **Norway spruce** [161] 3.0m o/c..

E Building Protection Hedge along top of berm selected 120m. Infill as needed 3.0m between existing plantings **single rows sugar maple (10), basswood (10), white spruce (20).** Plant and mulch as forestry planting. Remove thick understorey as needed.

F Building Protection Hedge 100m. **Single row White spruce** (33) 3.0 o/c

G Field and Buffer Protection Hedge 188m. **Single row White spruce** (63) 3.0 o/c

Figure 11: NVCA site plant reflecting actual planting for Case Study 2. This corresponds to Figure 8 of the site plan proposal.

Landowner

Location of planting

Phone:

Trees to be planted		Number
C. Blue spruce	Sb	300
White spruce	Sw	60
Nannyberry	Nb	30
Total Seedlings Planted:		390

Planting Area acres 0.00 hectares

Planting Site Information

Landuse: Mix of fallow and mown area.

Soil Type: Bennington fine sandy loam (vfs to fs)

Drainage: Moderate to well, Mottles 50cm+

Soil Depth: A=25cm, B=26-40, C is clayey.
No carbonates found.

Topography: gentle slope.

Competition: None - recently tilled or winter wheat.

Site Preparation Notes

Planting areas to be prepared by the landowner - sufficient tillage to ensure a level, worked area without lumps to a width of 3m (10'), and depth of 20cm (8"). NVCA will provide applicator and plastic mulch, landowner to provide tractor and driver.
NVCA will seed areas adjacent to plastic with a mixture of clover and barley, will also mow the area in year 1.

Access

See site plan.

Planting

Method: Hand.

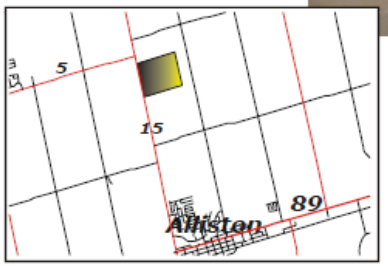
Spacing: See site plan. All planting holes to be filled with plastic squares and pinned at planting.

Tending

TBD

A

B



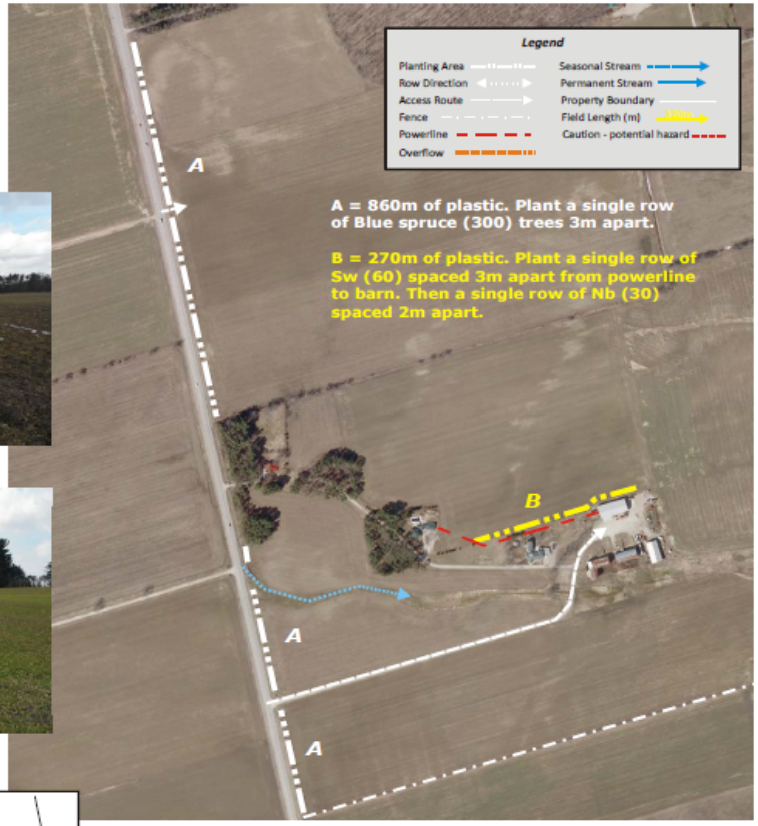


Figure 12: NVCA site plan for case study 2a. Note that no site plan proposal was rendered for this site.

Landowner			
Location of planting			
Phone:			

Trees to be planted		**Number**
European larch	Le	80
White spruce	Sw	80
Total Seedlings Planted:		160

Planting Area	acres	0.00 hectares

Planting Site Information	
Landuse:	Mix of fallow and winter wheat.
Soil Type:	Bennington fine sandy loam (vfs to fs)
Drainage:	Moderate to well, Mottles 40cm to 70cm
Soil Depth:	A=35, B=36+. Carbonates at B.
Topography:	gentle slope.
Competition:	None - recently tilled or winter wheat.

Site Preparation Notes

Planting areas to be prepared by the landowner - sufficient tillage to ensure a level, worked area without lumps to a width of 3m (10'), and depth of 20cm (8"). NVCA will provide applicator and plastic mulch, landowner to provide tractor and driver.
NVCA will seed areas adjacent to plastic with a mixture of clover and barley, will also mow the area in year 1.

Access

See site plan.

Planting	
Method:	Hand.
Spacing:	See site plan. All planting holes to be filled with plastic squares and pinned at planting.

Tending

TBD

. Figure 13: NVCA site plan reflecting actual windbreak planting for case study 3. This corresponds to Figure 9

Landowner

Location of planting

Work Phone:

Trees to be planted		**Number**
White spruce	Sw	80
European larch	Le	80
Poplar	Po	80
Red oak	Or	60
Black cherry	Cb	20
Total Seedlings Planted:		**320**

Planting Area acres 0.00 hectares

Planting Site Information

Landuse: Mix of active ag land and fallow.

Soil Type: Smithfield and Alliston sandy loams.

Drainage: tbd

Soil Depth: tbd

Topography: Flat

Competition: None in A and B, established thatch in section C

Site Preparation Notes

A and **B** - to be completed by Zander Sod, plow, disk and cultivate to flat, uniform planting bed. Tillage must extend a minimum of 8" (20cm) deep, 8' wide. NVCA to provide plastic mulch and applicator, Zander sod to arrange for tractor and driver.
NVCA will hand plant trees.
NVCA to broadcast white Dutch clover at 5pds/acre after tree planting along edges of plastic. NVCA to mow if required in July 2012.

C - NVCA to apply a shielded application of simazine+glyfos at 5.5 kg/ha+ Glyfos at 3l/ha 1-3 weeks after planting.

Access

Use farm lane off of the 10th Line.

Planting

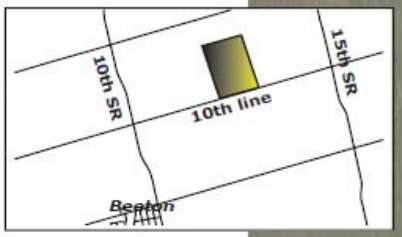
Method: Hand.

Spacing: A, B, C - trees 2m apart (6.5').

Follow site plan for species placement.

Tending

TBD.



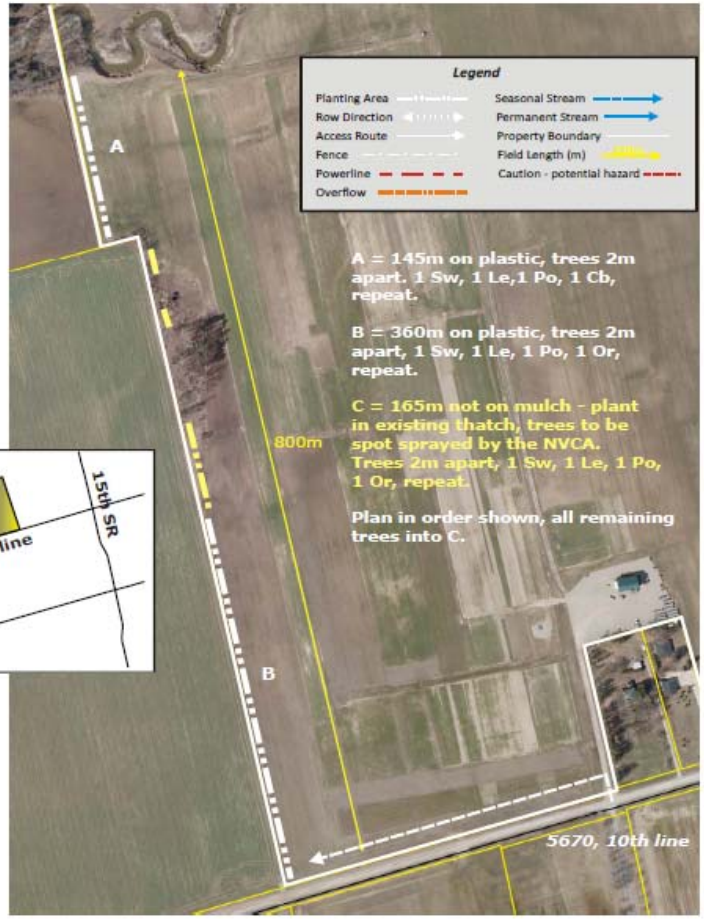


Figure 14: NVCA site plan reflective of actual windbreak plantings for case study 4. This corresponds to the rendered site plan in Figure 10.

Landowner			
Location of planting			
Cell Phone:			
Work Phone:			

Trees to be planted		**Number**
Norway spruce	Sn	400
White spruce	Sw	280
European larch	Le	80
Black Cherry	Cb	160
Red oak	Or	50
Hybrid poplar	Po	80
Total Seedlings Planted:		**1,050**

Planting Area	acres	0.00 hectares

Planting Site Information	
Landuse:	Mostly active farm land.
Soil Type:	Alliston and Tioga loamy sand.
Drainage:	Moderate - mottles 40-50cm.
Soil Depth:	A=40, B=41cm+ and is fine sand.
Topography:	Flat.
Competition:	None

Site Preparation Notes
A,B,C,D,F,G - WD Potato to prepare soil to uniform, flat, loose planting bed. NVCA to install plastic mulch with the assistance of WD Potato's tractor and driver. Hand plant into plastic, cover holes and pin as required. (950 trees).
E - shielded application of simazine+glyfos at same rate as riparian section (100 trees).

Access
From 3644 Sideroad 10, New Tecumseth.

Planting	
Method:	Hand.
Spacing:	A,C,D,E,F,G = 3m (10').
	B = 2m (6.5').
	A,B,C,D,F,G are on plastic mulch.
	E is in mown grass ontop of berm.

Tending
TBD

Shelterbelt Planting Plan

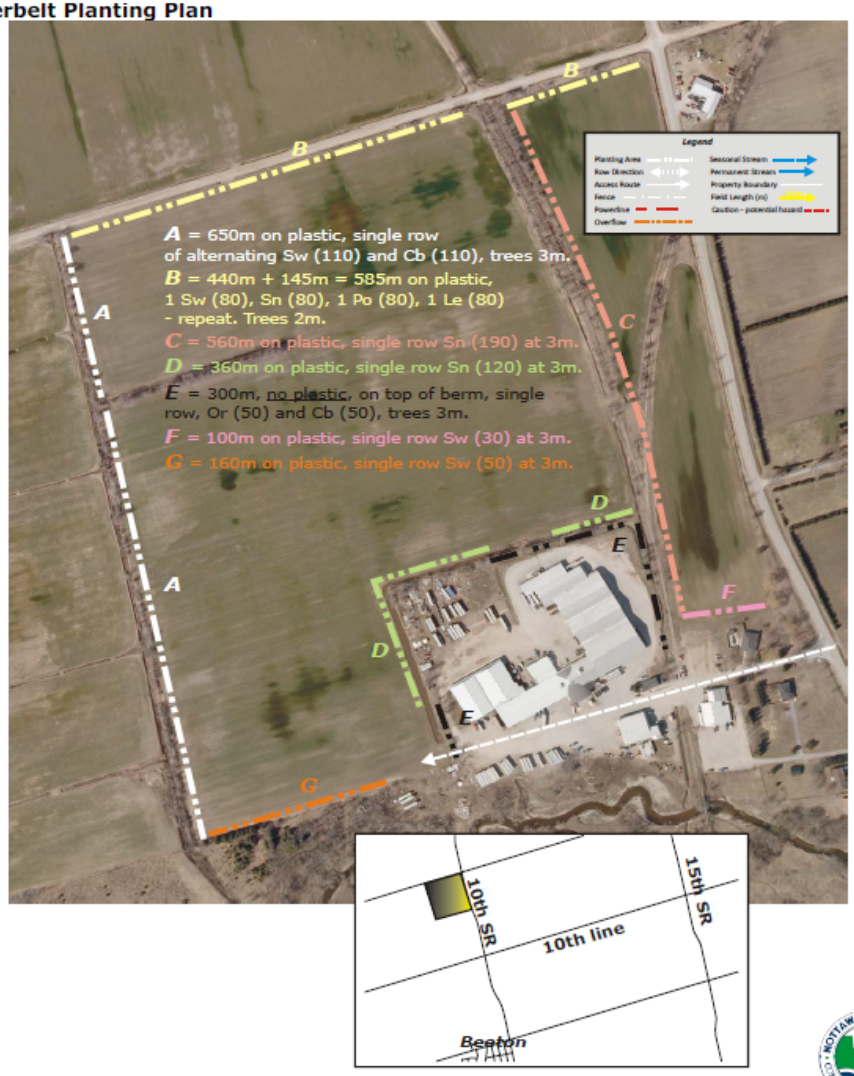
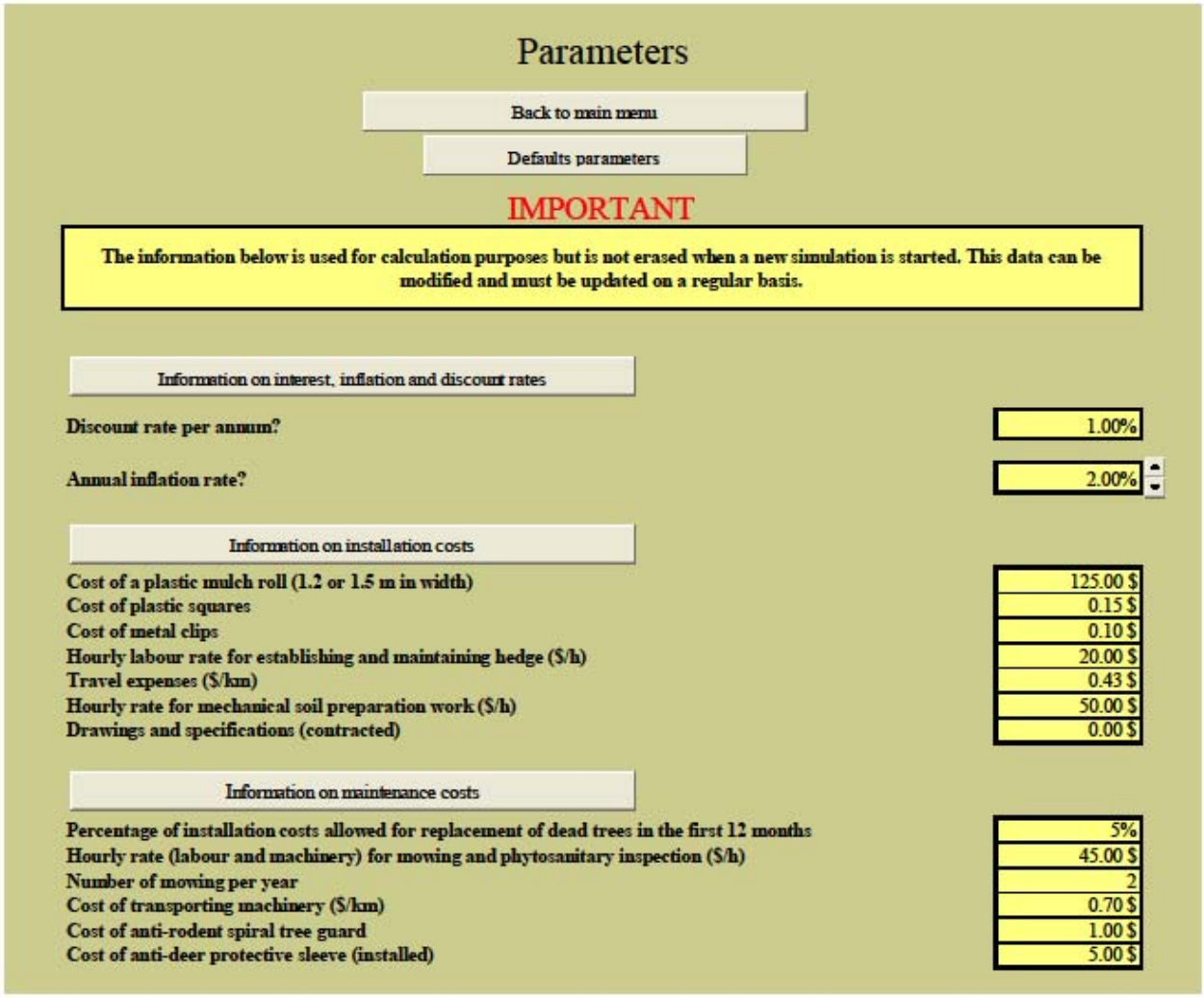


Figure 15: Economic model payback simulator calculations for Case Study 4, Windbreak D: parameters, questionnaire, and summary table.



Parameters

Back to main menu

Defaults parameters

IMPORTANT

The information below is used for calculation purposes but is not erased when a new simulation is started. This data can be modified and must be updated on a regular basis.

Information on interest, inflation and discount rates

Discount rate per annum?	1.00%
Annual inflation rate?	2.00%

Information on installation costs

Cost of a plastic mulch roll (1.2 or 1.5 m in width)	125.00 $
Cost of plastic squares	0.15 $
Cost of metal clips	0.10 $
Hourly labour rate for establishing and maintaining hedge ($/h)	20.00 $
Travel expenses ($/km)	0.43 $
Hourly rate for mechanical soil preparation work ($/h)	50.00 $
Drawings and specifications (contracted)	0.00 $

Information on maintenance costs

Percentage of installation costs allowed for replacement of dead trees in the first 12 months	5%
Hourly rate (labour and machinery) for mowing and phytosanitary inspection ($/h)	45.00 $
Number of mowing per year	2
Cost of transporting machinery ($/km)	0.70 $
Cost of anti-rodent spiral tree guard	1.00 $
Cost of anti-deer protective sleeve (installed)	5.00 $

Figure 15 continued

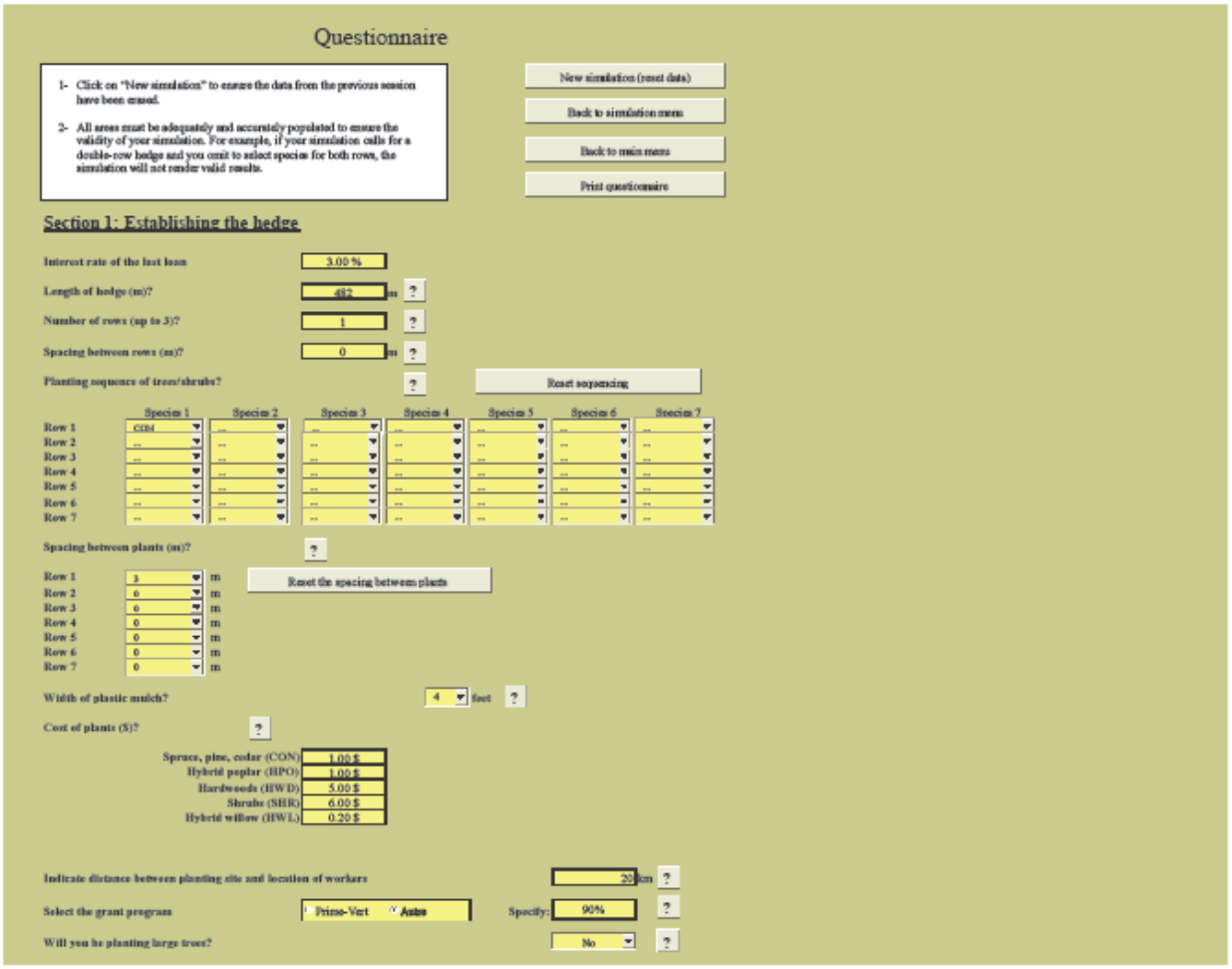


Figure 15 continued

Summary Table

(increase in cumulative discounted margin)

Payback	11 years	**Carbon sequestered (ton CO^2 equivalent) after 40 years**	**58**

Period	Improvements in incomes	Decreases in incomes	Margin (improvements-decreases)	Discounted margin	Cumulative discounted margin
0-5 years	0 $	-424 $	-424 $	-413 $	-413 $
5-10 years	720 $	-455 $	265 $	245 $	-168 $
10-20 years	5,380 $	-1,136 $	4,244 $	3,639 $	3,470 $
20-40 years	25,980 $	-3,636 $	22,343 $	16,507 $	19,977 $

Appendixes

Appendix 1: Multi-functional Windbreak Workshop: January 17 and 18, 2012

Overview:
The project completed two windbreak workshops on January 17, 2012 for agroforestry, forestry, and outreach staff and on Janaury 18, 2012 for the agricultural community. The workshops, entitled "A New Perspective on Windbreaks: Multi-functionality Workshop" was held at the Nottawasaga Inn in Alliston, ON. The objective of the workshop was to provide professionals and the agricultural community with an introduction to the potential opportunities and benefits of multi-functional windbreaks and windbreaks, to promote the concepts of multi-functional windbreaks and shelter belts, etc. The workshop topics included:

- Shelter belt design and planting
- Benefits, costs and cost-sharing programs
- Maintenance and trade-offs
- Economic opportunities of multifunctional windbreaks and windbreaks.

Workshop presenters included André Vézina (Institut de Technologie Agroalimentair), John Kort (PFRA), Brad Peterson (C. Brad Peterson), Nathan Munn (GRCA), Jason Deveau (OMAFRA), Paul Day (Trees for Mapleton), and Shannon Stephens (NVCA).

The January 17, 2012 workshop was also provided as an OMAFRA-produced webinar.

Attendance:
Forty seven (47) agroforesty, stewardship professional/practitioners attended the January 17, 2012 multi functional windbreak workshop. Present included staff from conservation authorities, OMAFRA, MNR, MTO, AAFC, municipalities, Trees Ontario, Trees for Mapleton, landscape architects/contractors, and NGOs. In addition, 22 people signed up for webinar with attendance from conservation authorities, Conservation Ontario, University of Guelph, and provincial agencies.

Thirty seven (37) farmers attended the January 18, 2012 multi functional windbreak workshop. Various sectors were present at the workshop included potato, sod, organic, cash crop, hobby farm, and livestock from Simcoe, Durham, Peel, Grey-Bruce, etc. Further, OFA and the Christian Farmers associated were both present as was the Ontario Potato Board and the Holland Marsh growers Association.

Communications:
The January 17, 2012 workshop was advertised mostly through personalized email to the various agencies and bulk email via the Conservation Ontario Forestry and Stewardship contact list in addition to online advertisement on Trees Ontario.

The January 18, 2012 workshop was advertised through 1) a mail out invitation provided to the agricultural community multi-functional windbreak survey list; 2) the Simcoe Federation of Agriculture (OFA); 3) local networks, and 4) local agricultural and municipal media outlets through paid advertisement and a 'conservation corner' article. The conservation corner article was picked up by simcoe.com; the Wasaga Sun.

Post-workshop Knowledge/communication transfer:
The OMAFRA-recorded webinar presentations (wmv format) and presentations (as pdf) are provided online at http://www.wbvecan.ca/anglais/document.html. The workshop participants were emailed the location of the webinars/presentations for access.

A post-press release on the Windbreak workshop is scheduled for publishing in *Farm View* for the May edition. The text is on the website Farmviewonline.com.

Multifunctional Field Windbreak Workshop

Tuesday, January 17, 2012

Nottawasaga Inn, Alliston, ON

8:30-8:45	Introduction (Ryan Post, NVCA; Peter Roberts, OMAFRA)
8:45-9:00	Multifunctionality in agriculture: origin of the concept (André Vézina)
9:00-10:15	Benefits from field windbreaks for crops and for the environment (John Kort, PFRA)
10:15-10:35	Break
10:35-11:00	Field wind break implementation and maintenance: a quick review (André Vézina)
11:00-11:25	Farmers' concerns about field windbreaks and shelterbelts in their fields (GRCA experience; Nathan Munn, GRCA)
11:25-11:40	Trees for Mapleton - a good news story (Paul Day, Chair, Trees for Mapleton)
11:40-12:45	Lunch
12:45-1:15	Vegetative barriers to pesticide drift (Dr. Jason Deveau, OMAFRA)
1:15-3:00	Designing multifunctional field windbreaks (Andre Vézina and Brad Peterson)
3:00-3:15	Afternoon Break
3:15-4:00	Multifunctional field windbreaks: can it be profitable? (André Vézina and Brad Peterson)
4:00-4:30	Panel discussion

Multifunctional Field Windbreak Workshop

Wednesday, January 18, 2012

Nottawasaga Inn, Alliston, ON

8:30-8:45	Introduction (Ryan Post, NVCA and Peter Roberts, OMAFRA)
8:45-9:00	Multifunctionality in agriculture: origin of the concept (André Vézina)
9:00-10:15	Benefits from field windbreaks for crops and for the environment (John Kort, PFRA)
10:15-10:30	Break
10:30-10:55	Field windbreak implementation and maintenance: a quick review (André Vézina)
10:55-11:20	Farmers' concerns about field windbreaks and shelterbelts in their fields (GRCA experience; Nathan Munn, GRCA)
11:20-11:45	Vegetative barriers to pesticide drift (Dr. Jason Deveau, OMAFRA)
11:45-12:45	Lunch
12:45-2:45	Designing multifunctional field windbreaks (Andre Vézina and Brad Peterson)
2:45-3:00	Afternoon Break
3:00-3:45	Multifunctional field windbreaks: can it be profitable? (André Vézina and Brad Peterson)
3:45-4:00	Stewardship opportunities (Shannon Stephens, NVCA)
4:00-4:30	Panel discussion and workshop wrap-up

January 18, 2012 Workshop Evaluation Summary

Thirty seven (37) farmers attended the January 18, 2012 multi functional windbreak workshop at the Nottawasaga Inn. Twenty four (24) of the 27 farmers provided an evaluation of the workshop. The summary of the evaluations is provided below.

Question 1: Did you register for the field windbreak workshop (check as many as appropriate)

to learn more about the benefits of windbreaks to crop production	21 out of 24 respondents
to learn how to design a field windbreak	19 out of 24 respondents
to learn where to obtain planting stock for field windbreaks	11 out of 24 respondents
to learn how to maintain field windbreaks	11 out of 24 respondents
to learn how to obtain revenues from my field windbreaks	9 out of 24 respondents
other reason (provide comments)	6 out of 24 respondents Comments: • windbreaks and how to use them for livestock • networking with professionals in environment and farming • to provide synopsis and boost awareness through farm view newspaper • environmental advantages and benefits to society

Question 2: In the end did you get the information needed from the speakers and discussions

Yes	24 out of 24 respondents
No	0

Comments:

- more info on maintenance
- I was able to ask one on one how to effectively use windbreaks for livestock
- More information than one may expect on the subject- very thorough
- hope to access the presentations on website

Question 3: Was there adequate opportunity to interact with other farmers and the presenters

Yes	22 out of 24 respondents
No	2 out of 24 respondents

Comments:

- always use more time!
- group discussions would add to the day

Question 4: Have we missed anything that should have been presented

- excellent job
- well covered, thanks
- not that I am aware of
- what are the positive effects for livestock when incorporating windbreaks
- examples or panel of farmers who have had successes would be awesome, but the event was great
- very well covered and websites provided for questions
- no, very thorough
- more on funding opportunities

Question 5: If we hold a follow-up workshop what would you like to see presented that would be of interest to Ontario farmers

- specific info on local markets for various species used in windbreaks
- follow up to see how we did with our windbreaks
- unsure
- program wide program to help with smaller scale projects
- more crop options, cover crops
- panel of farmers working with windbreaks
- marketing help for biodiverse products
- I'll think on it
- more farmers at workshop
- actual projects that farmers have undertaken at various stages. Their own experiences with developing windbreaks
- grant programs to assist with plantings

Question 6: Were the location and hotel facilities suitable for this kind of workshop

Yes	24 out of 24 respondents
No	0

Comments:

- very nice
- good room, excellent lunch; coffee, tea and snacks were appreciated

Question 7: What other information would help you make windbreaks more profitable on your farm operations

- specific resource guide on trees and shrubs- their hardiness, possible diseases to watch for
- specific varieties that would suit my farm
- positive effects on livestock cow calk operations
- incentive programs to get started. Maybe a paid management program to reward for the early upkeep of these seedlings
- places to obtain edible plants (berry bushes) at cheaper costs with co-op buy in
- improvement ideas for existing/native hedge rows. Can you transplant trees and shrubs from another location on farm to the windbreak
- excellent information on economics

Question 8: Did this workshop help in your decision-making about windbreaks

Yes	24 out of 24 respondents
No	0

Comments:

- despite not having a specific use for a windbreak personally, the information on types and benefits of certain species was good

Question 9: If you have any other comments to make, please provide them here

- excellent program, please run again
- I did not realize how profitable a wind break could be.
- The power point would be an asset to have - could not copy down all the info
- great initiative, thanks
- too long! Could have been more succinct, i.e. lots of overlap info however, info presented was useful and informative
- very good, thanks
- audio was good. A later start may be worthy of consideration; another time.
  it was a fantastic day with a delicious meal. Thanks!

FOR IMMEDIATE RELEASE

FARMERS ENCOURAGED TO BUILD WINDBREAKS TO PROTECT SOIL AND IMPROVE YIELD
Free workshop provides expert guidance

UTOPIA, Ontario, January 4, 2012 – Farmers can reduce expensive losses caused by wind and water erosion by planting trees in key locations in a formation known as a windbreak. A free workshop teaching farmers the value of windbreaks and how to construct them will be held on January 18 in Alliston, hosted by the Nottawasaga Valley Conservation Authority (NVCA) and the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA).

Windbreaks do exactly what they say – break the rush of wind over farmland, preventing loss of topsoil, seed and plants.

“Windbreaks work their magic by improving soil moisture as well as soil and air temperatures, and decreasing evaporation and wind speed,” says Shannon Stephens, Healthy Waters Program Coordinator with the NVCA. “Research has consistently shown that using windbreaks results in higher crop yields, earlier planting, faster germination, earlier flowering, better pollination and reduced pesticide spray-drift.”

Windborne soil is not only a loss for farmers; it also winds up in lakes and streams, where ingredients such as phosphorous can damage the habitat of fish, insects and other water-dwellers. Windbreaks can improve the quality of water far downstream from where they are planted.

The workshop will have national, provincial and conservation authority experts presenting on all aspects of windbreaks to increase understanding of their value and to provide expert advice on how best to construct and cultivate them over the long term. Speakers will include: André Vézina, Agroforestry Specialist; Dr. John Kort, Shelterbelt Biologist and Agroforester; Brad Peterson, Environmental Management and Landscape Architecture; Nathan Munn, Forestry Specialist with the Grand River Conservation Authority; and Dr. Jason Deveau, Application Technology Specialist with OMAFRA.

Members of the farming community are encouraged to register for this free seminar by contacting Ryan Post of the NVCA at 705-424-1479 or rpost@nvca.on.ca.

The Nottawasaga Valley Conservation Authority is a public agency dedicated to the preservation of a healthy environment through specialized programs to protect, conserve and enhance our water, wetlands, forests and lands.

-30-

Appendix 2: NVCA Mail-out and Workshop Windbreak Survey Summary

1.0 INTRODUCTION

The Lake Simcoe Protection Plan is focused on phosphorus (P) load reduction to improve water quality and the long-term health of the watershed. A significant portion of the P load is attributed to atmospheric deposition of soil-bound P. Preliminary research indicates the bulk of this atmospheric load to Lake Simcoe is due to windborne erosion from agricultural soils to the north and west of the watershed, encompassing NVCA lands dominated by fine-grained Tioga loams and associated high value agriculture.

In 2011-2012, the Nottawasaga Valley Conservation Authority and OMAFRA with funding through the provincial Lake Simcoe funding program undertook a multi-phase windbreak project. The objective of the project was to educate farmers and extension professional on the use of multi-functional windbreaks/wind breaks, to increase the adoption of new windbreaks by farmers by highlighting planting and design options that will realize different economic gains.

Windbreaks are rows of trees or shrubs arranged on the landscape to reduce wind speed. They may consist of either perennial plants such as trees, shrubs, annual crops, such as corn, or other materials such as fences. The porosity and tree height of the windbreak are the main factors in determining how effective the windbreak will be. A well designed windbreak will protect an areas downwind of approximate 10 to 15 times the height of the windbreak. Thus, a 30 foot tall windbreak will protect and area 300 to 450 feet downwind. Multi-functions of windbreak include livestock protection, reducing building heating costs, as well as arresting soil sedimentation and erosion by wind and water, creating favourable microclimates for field crops, providing opportunities for farm income diversification through biomass and market crops, and increasing aesthetic values.

Outstanding in Simcoe County is the agricultural community perception of windbreaks including multifunctional windbreaks and windbreaks. A survey was developed to solicit input on windbreaks and windbreaks and to assess the interest, potential barriers, and opportunities. In addition, the survey is to help focus Ontario-specific windbreak research and extension programs delivered by OMAFRA, Conservation Authorities and various extension staff.

2.0 SURVEY METHODOLOGY

Mail out:

The targeted audience for the mail out was the general farming community in south Simceoe County which included the following sectors: potato, sod, carrot, onions, cash crop (corn, soya bean,etc), and livestock. The NVCA-administered survey had a total of 24 questions which consisted of yes/no or select responses style of questions that were grouped into the following themes: perceptions about field windbreaks; history of field windbreak establishments on your farm, history of field windbreak removal, your farm operation, and next generation windbreaks/windbreaks.

The mailing list was developed using pre-existing mailing lists combined with addresses generated from the municipal tax rolls. To increase the rate of return, NVCA letter head was used. On July 22, 2011, the questionnaire, cover letter, and self addressed envelopes were mailed to roughly 100 farming operations in south Simcoe County.

The response rate was 15% (15 out of the 100 surveys were returned). There were approximately 10 surveys that were undeliverable because of address change, incorrect addresses, etc. The survey results were amalgamated to ensure confidentiality with the individual and collected for general research purposes only.

Workshop:

In addition to the July, 2011 survey mail out, the identical survey was provided to the attendees at the multifunctional windbreak workshop on January 18, 2012 in Alliston, Ontario. In total, 37 producers attended the workshop. Various sectors and geographies were represented at the workshop including

livestock, potato, sod, cash crop, equine, and organic from Simcoe, Durham, Peel, and Grey, etc counties. As part of their agenda package, each participant was provided with a survey with a self addressed envelope.

Eight completed surveys were received from the workshop participants, for a response rate of 20%. The survey results were amalgamated to ensure confidentiality with the individual.

3.0 SUMMARY OF SURVEY RESPONSES:

3.1 PERCEPTIONS ABOUT FIELD WINDBREAKS

Question 1: How do you perceive the presence of mature field windbreaks on property/farmland values?

	Mail respondents (n=15)	Workshop respondents (n=8)
Sizeable increases in value	2	3
Some increase in value	7	5
No effect on value	6	
Negative effect on value		

Question 2: How do you perceive the effect of mature field windbreaks on crop production in fields protected by windbreaks?

	Mail respondents (n=15)	Workshop respondents (n=8)
Sizeable yield increase	3	3
Some yield increase	9	5
Some yield decrease		
Sizable economic loss		
No yield effect	3	

Question 3: Is soil erosion (by wind or water) occurring on your farm?

	Mail respondents (n=15)	Workshop respondents (n=8)
Yes	13	4
No	2	3
Not sure		
No response		1

Question 4: How important would you consider the usefulness of wind breaks for controlling soil erosion?

	Mail respondents (n=15)	Workshop respondents (n=8)
Definite Value	7	7
Some Value	8	1
No Value		

Question 5: Has the topic of windbreaks ever come up in conversation with farmers in your area?

	Mail respondents (n=15)	Workshop respondents (n=8)
Yes	8	5
No	7	2
No response		1

3.2 HISTORY OF FIELD WINDBREAK ESTABLISHMENT AND MAINTENANCE ON YOUR FARM

Question 6: Are there any vegetative (shrub or trees) windbreaks on your property? Check all that apply

	Mail respondents (n=15)	Workshop respondents (n=8)
Surrounding each field	3	2
Only on the farm property lines	9	3
Only surrounding the home/barns	3	1
Both around the barns and fields	4	1
Don't know/Not Applicable	1	
Other	1	
No Response	1	1

Question 7: If yes, what are the oldest windbreaks on your farm? Please check 1 category

	Mail out respondents (n=15)	Workshop respondents (n=8)
0-5 years	1	2
6-10 years	2	1
11-15 years	1	1
16-20 years		
21+ years	10	2
No Response	1	2

Question 8: Was the work done under an environmental cost share program?

	Mail respondents (n=15)	Workshop respondents (n=8)
Yes	3	3
No	11	4
No response	1	1

Question 9: For what reason(s) was the FIELD windbreak established? Check ONE primary reason and as many secondary reasons as apply.

	Mail respondents (n=15)			Workshop respondents (n=8)		
	Primary	Secondary	Not a Consideration	Primary	Secondary	Not a Consideration
Crop yield improvements	4	3	1	2	2	1
Soil conservation (erosion control)	9	3	1	5	2	
Aesthetic (appearance) considerations	2	4	1	1	3	
Cattle protection during winter grazing			6	1		3
Increase value of property	1	2	4	2		1
Snow management	2	4	2	1	2	

Provide wildlife habitat	1	2	6	2	3	1
Trees to be used for firewood, pests, etc			7	1	2	1
Not a Consideration Generate other non-timber revenue (e.g. supplemental crops)			6		1	3
No Response	1					

Question 10: How often do you maintain your windbreaks by thinning, pruning or planting new stock in gaps in the windbreak?

	Mail respondents (n=15)	Workshop respondents (n=8)
Yearly	1	2
Every 2-5 years	2	2
Every 5 – 10	2	
Every 10 year plus		
Never	9	3
No response	1	1

Question 11: Would you be interested in having an agroforester, agent, or other specialist provide you with information regarding windbreak maintenance?

	Mail respondents (n=15)	Workshop respondents (n=8)
Yes	5	7
No	10	1

Question 12: Check the types of maintenance activities carried out on some or all of the windbreaks on your property.

	Mail respondents (n=15)	Workshop respondents (n=8)
Tree trimming and thinning	4	3
Removal of dead and diseased trees	9	7
Replanting	4	5
Fencing		2
Spraying for tree pests	1	
Other	1	1
No Response	4	

3.3 HISTORY OF FIELD WINDBREAK REMOVAL

Question 13: Have any field windbreaks (or portions thereof) been removed from the farm you now operate?

	Mail respondents (n=15)	Workshop respondents (n=8)
Yes	7	3
No	5	2
Don't know	3	3

Question 14: If yes, were any of the costs for removal covered by the value wood and anticipated sale of timber from trees or other vegetation of in the windbreak?

	Mail respondents (n=15)	Workshop respondents (n=8)
Yes	2	1
No	5	2
Don't know	3	3
No response	5	2

Question 15: How many rows did the windbreak(s) have?

	Mail respondents (n=15)	Workshop respondents (n=8)
1-5 rows	10	4
6-10 rows		
11-15 rows		
over 15 rows		
None	2	
No Response	3	4

Question 16: What was the condition of the windbreak when removed?

	Mail respondents (n=15)	Workshop respondents (n=8)
Excellent	1	
Good		1
Fair	3	
Poor	3	1
Don't Know	3	1
No Response	5	5

Question 17: For what reason(s) was the FIELD windbreak(s) removed? Check all that apply

	Mail respondents (n=15)	Workshop respondents (n=8)
Age and condition of windbreak	2	2
Preparation for new windbreak	1	
Windbreak competing with crops	1	1
Conflict with farming practices	4	2
No economic value of land in windbreak	1	2
Conflict with irrigation development	1	
Caused excessive snow accumulation on roads		
Right-of-way expansion for road		
Consolidation of added fields	1	1
Other, Please Specify		
No Response	8	5

3.4 YOUR FARM OPERATION

Question 18: What commodities do you have on your farm? Check all that apply

	Mail respondents (n=15)	Workshop respondents (n=8)
Potato	9	1
Row crops – no till	4	2
Row crops – conventional till	4	2
Cash crops – carrots, onions, oriental vegetables		1
Sod	1	1
Corn	6	3
Soya	4	4
Livestock	3	3
Other, please specify	7	6

Question 19: Do you currently:

	Mail respondents (n=15)	Workshop respondents (n=8)
Own all your farm/land	3	1
Rent all your farm/land		
Own and rent farm/land	12	6
Neither own or rent, but work on this farm/land		
No response		1

Question 20: What is the size of the property you own?

	Mail respondents (n=15)	Workshop respondents (n=7)
1 – 25 acres		
25 – 50 acres		2
51 - 100 acres	1	
101 - 250 acres	6	2
More than 250 acres	8	3
Not Applicable		

Question 21: What is the size of the property you presently rent?

	Mail respondents (n=15)	Workshop respondents (n=6)
1 – 25 acres		
25 – 50 acres		
51 - 100 acres	1	1
101 - 250 acres	2	2
More than 250 acres	9	2
Not Applicable	3	1

3.5 NEXT GENERATION WINDBREAKS/WINDBREAKS

Question 22: How likely is it that you will build new wind breaks in your property?

	Mail respondents (n=15)	Workshop respondents (n=8)
Very Likely	4	6
Likely	3	
Unlikely	8	1
No response		1

Question 23: Would you like assistance with the layout and design of a windbreak that could include features to provide new revenue streams such as inter-cropping between windbreak rows?

	Mail respondents (n=15)	Workshop respondents (n=8)
Yes	2	6
No	6	2
Ask me another time	6	
No Response	1	

4.0 DISCUSSION

Perceptions about Field Windbreaks:
The majority of respondents indicated that mature field windbreaks had a sizeable to some increase in the property/farmland value and also with crop production in fields that are protected by windbreaks. Similarly, the majority of respondents indicated that soil erosion (wind or water) was occurring on their individual farms. It is important to note that the 88% workshop respondents indicated definite value in

windbreaks controlling soil erosion while 47% respondents indicated definite values and 53% some value. Importantly, no respondent indicated that windbreaks had no value in controlling wind erosion.

Within the community the mail respondents indicated a 47-53% spilt in discussing windbreaks with local farmers, whereas 63% of the workshop respondents indicated that discussing windbreaks with other farmers suggesting that windbreaks are on the radar.

History of field windbreaks establishment and maintenance on your farm:
Respondents indicated that the oldest on-farm windbreaks are generally 21+ years old and are typically located only on farm property lines and, secondarily surrounding each field, only surrounding the home/barn, or both around the barn and fields. Interestingly, 79% of the mail in respondents indicated that the work done for windbreak was not covered under an environmental cost share program (e.g. EFP) where as 3 out of 7 respondents from the workshop was covered under EFP.

The general reason for field wind break establishment among both responding groups was soil conservation (erosion control) followed by crop yield improvements. Conversely, provide wildlife habitat; trees to be used for firewood, pest prevention; and to generate other non-timber revenue were three areas where the respondents did not considered as reason for wind break establishment. This is interesting since these are supporting concepts behind multi-functionality windbreaks. It is noted that cattle protection during winter grazing was also seen as a low priority consideration given that the south Simcoe agricultural landscape is typically livestock/cattle-poor.

Windbreak maintenance including, but not limited to thinning, pruning, or planting new stock in gaps of the windbreaks was never completed by 60% of the mail in respondents and 3 out of 7 workshop respondents. However the other survey population regarding maintenance is the yearly to 2-5 year category. When maintenance occurs, it generally consists of removal of dead trees and diseased trees followed by tree trimming and replanting.

History of field windbreak removal:
Most respondents indicated that field windbreaks (or portions thereof) have been removed from the farm and that there were no costs covered for the removal by the value wood and the anticipated sale of timber from trees or other vegetation of the windbreak. The size of the removed windbreaks was predominately 1-5 rows. This suggests that either, the opportunity to sell the wood was not pursued, or the market opportunity doesn't exist, or as indicated previously, the establishment of windbreaks for the future generation of revenue was not considered. In general, a variety of reasons were provided regarding the removal of field windbreaks with conflict with farming practices noted as a common theme.

Your farm operation:
The majority of the mail in respondents grew potatoes along with corn and other; where the majority of workshop respondents grew other and soya crops. The vast number of respondents own and rented farm typically owning between 100 to more than 250 acres and renting generally more than 250 acres. This relates to the large-scale farming operations in south Simcoe County.

Next Generation:
53% of mail in respondents indicated that there are not likely to build a new windbreak while only 27% indicated that they were very likely to plant a new windbreak. However, 75% of the workshop respondent indicated that they were very likely to establish a new windbreak. This should not be surprising since the workshop attendees are believed to be interested in windbreaks simply by their attendance.

Regarding assistance with the layout and design of a windbreak that could include features to provide new revenues streams such as inter-cropping, only 2 out of the 15 mail out respondents were interested and 6 were stated not interested. This is compared with 6 out of 8 respondents at the workshop that are interested in receiving assistance.

5.0 CONCLUSIONS

- From the two surveys, it is indicated that the participating agricultural community have a broad positive awareness of how windbreaks benefitted property value and crop yields along with the positive correlation of windbreaks and on-field soil erosion.

- Windbreaks are generally older than 20 years old with a significant number of respondents indicated that they never completed maintenance on their windbreaks.

- Environmental cost share program (e.g. EFP) was not used extensively for the establishment of the windbreaks.

- Establishment of windbreaks was for on-field issues such as controlling soil erosion and crop yield improvements. 'multi functionality' components, e.g. timber revenue source, were not considered.

- A common theme surrounding the removal of wind breaks was conflict with farming practices.

- Removed wind breaks were predominantly 1-5 rows.

- 53% of mail in respondents indicated that there are not likely to build a new windbreak property while only 27% indicated that they were very likely to plant a new windbreak. However, 75% of the workshop respondent indicated that they were very likely to establish a new windbreak.

Field Wind Break Survey and associated covering letter

Date
Address

RE: farm windbreaks survey

Dear:

Farmers in the Nottawasaga Valley watershed are experienced producers and have shown a willingness to adopt innovative practices which increase yields yet are sensitive to the surrounding environment. OMAFRA and its partners are looking for ways to encourage more windbreaks at key locations within the Nottawasaga watershed to help increase yields, reduce soil loss and improve water quality. Windbreaks are becoming less common and new advances in their design and placement is being explored by OMAFRA to hopefully increase the number and types of windbreaks present on farms.

The attached survey will help to focus windbreak research and extension programs delivered by OMAFRA, extension staff, and local Conservation Authorities. Every effort will be made to protect this information and your confidentiality. Survey results will be based on grouped data and will not reveal individual responses. Funding for the survey is provided by OMAFRA.

Your time and help is greatly appreciated. A phosphorus soil test will be provided to the first 20 people who return a completed survey.

Please feel free to contact Ryan Post at 705-424-1479 ext 249 or via email at rpost@nvca.on.ca if you have any questions.

Sincerely

Ryan Post
Hydrogeologist
Nottawasaga Valley Conservation Authority
8195 8th Line
Utopia, Ontario
LOM 1T0

PERCEPTIONS ABOUT FIELD WINDBREAKS

1. How do you perceive the presence of mature field windbreaks on property/farmland values? (CHECK ONE (√))

- ☐ Sizeable increases in value
- ☐ Some increase in value
- ☐ No effect on value
- ☐ Negative effect on value

2. How do you perceive the effect of mature field windbreaks on crop production in fields protected by windbreaks? (CHECK ONE (√)

- ☐ Sizeable yield increase
- ☐ Some yield increase
- ☐ Some yield decrease
- ☐ Sizable economic loss
- ☐ No yield effect

3. Is soil erosion (by wind or water) occurring on your farm?

☐ Yes ☐ No ☐ Not Sure

4. How important would you consider the usefulness of wind breaks for controlling soil erosion?

☐ Definite Value ☐ Some Value ☐ No Value

5. Has the topic of windbreaks ever come up in conversation with farmers in your area?

☐ Yes ☐ No

HISTORY OF FIELD WINDBREAK ESTABLISHMENT AND MAINTENANCE ON YOUR FARM

6. Are there any vegetative (shrub or trees) windbreaks on your property? Check all that apply

___ Surrounding each field
___ Only on the farm property lines
___ Only surrounding the home/barns
___ Both around the barns and fields.
___ Don't know/Not Applicable

7. If yes, what are the oldest windbreaks on your farm: Please check (√) one category

___ 0-5 years
___ 6-10 years
___ 11-15 years
___ 16-20 years
___ 21+ years

8. Was the work done under an environmental cost share program?

☐ Yes ☐ No

9. For what reason(s) was the FIELD windbreak established? Check (√) ONE primary reason and as many secondary reasons as apply.

	Primary Reason	Secondary Reasons	Not a consideration
Crop yield improvements			
Soil conservation (erosion control)			
Aesthetic (appearance) considerations.			
Cattle protection during winter grazing			
Increase value of property			
Snow management			
Provide wildlife habitat			
Trees to be used for firewood, pests, etc			
Generate other non-timber revenue (e.g. supplemental crops)			

10. How often do you maintain your windbreaks by thinning, pruning or planting new stock in gaps in the windbreak (Check (√) ONE)?

___ Yearly
___ Every 2-5 years
___ Every 5 – 10
___ Every 10 year plus
___ Never

11. Would you be interested in having an agroforester, soil extension agent, or other specialist provide you with information regarding windbreak maintenance?

☐ Yes ☐ No

12. Check (√) the types of maintenance activities carried out on some or all of the windbreaks on your property.

☐ Tree trimming and thinning
☐ Removal of dead and diseased trees
☐ Replanting
☐ Fencing
☐ Spraying for tree pests
☐ Other. Please Specify_____

HISTORY OF FIELD WINDBREAK REMOVAL

13. Have any field windbreaks (or portions thereof) been removed from the farm you now operate? Check (√) ONE

☐ Yes ☐ No ☐ Don't know

14. If yes, were any of the costs for removal covered by the value of wood and anticipated sale of timber from trees or other vegetation in the windbreak? Check (√) ONE

☐ Yes ☐ No ☐ Don't know

15. How many rows did the windbreak(s) have? _____Rows

16. What was the condition of the windbreak when removed? Check (√) ONE

☐ Excellent ☐ Good ☐ Fair ☐ Poor ☐ Don't Know

17. For what reason(s) was the FIELD windbreak(s) removed? Check ONE (√) Primary Reason and as many Secondary Reasons as apply.

	Primary Reason	Secondary Reasons	Not a consideration
Age and condition of windbreak			
Preparation for new windbreak			
Windbreak competing with crops			
Conflict with farming practices			
No economic value of land in windbreak			
Conflict with irrigation development			
Caused excessive snow accumulation on roads			
Right-of-way expansion for road			
Consolidation of added fields			
Other, Please Specify			

YOUR FARM OPERATION

18. What commodities do you have on your farm? (CHECK ALL APPLY)

___ Potato
___ Row crops – no till
___ Row crops – conventional till
___ Cash crops – carrots, onions, oriental vegetables
___ Sod
___ Corn
___ Soya
___ Livestock
____ Other, please specify _____

19. Do you currently:

___ Own all your farm/land
___ Rent all your farm/land
___ Own and rent farm/land
___ Neither own or rent, but work on this farm/land

20. What is the size of the property you own? (own only, rent is next question)

___ 1 – 25 acres
___ 25 – 50 acres
___ 51 - 100 acres
___ 101 - 250 acres
___ More than 250 acres
___ Not Applicable

21. What is the size of the property you presently rent?

___ 1 – 25 acres
___ 25 – 50 acres
___ 51 - 100 acres
___ 101 - 250 acres
___ More than 250 acres
___ Not Applicable

NEXT GENERATION WINDBREAKS/WINDBREAKS

22. How likely is it that you will build new wind breaks in your property?

☐ Very Likely ☐ Likely ☐ Not Very Likely

23. Would you like assistance with the layout and design of a windbreak that could include features to provide new revenue streams such as inter-cropping between windbreak rows?

☐ Yes ☐ No ☐ Ask Me Another Time

24. Would you be interested in attending a Windbreak Workshop in Lake Simcoe County this fall or winter of 2012 featuring new windbreak designs and potential economic returns from various designs? If ***yes***, please enter your **name and address below** so we can contact you about the location and other workshop details this fall.

Thank you for the time you have taken to complete this survey. Your time is very much appreciated.

*This survey was adapted from thesis work of Kim Tomczak, University of Nebraska, 2009.

Appendix 3: Southwest Diagnostic Farm Days (July 4, 2011) Windbreak Survey Summary

1.0 PURPOSE

The purpose of this survey is to help focus Ontario-specific windbreak research and extension programs delivered by OMAFRA, Conservation Authorities and various extension staff. The survey information collected is for general research purposes only.

2.0 SURVEY METHODOLOGY

The survey was provided to the participants at the Southwest Diagnostic Farm Days on July 4, 2011 in London, Ontario. The OMAFRA-administered survey had a total of 17 questions which consisted of yes/no or select responses style of questions. The questions were broadly tailored to solicit input on windbreaks and to assess the interest, potential barriers, and opportunities. In addition, the survey is to help focus Ontario-specific windbreak research and extension programs delivered by OMAFRA, Conservation Authorities and various extension staff.

A total of 7 responses were provided from this survey.

3.0 Summary of survey responses:

Question 1: Are you actively managing soil erosion on your farm? (Check One)

	Response (out of 7)
Yes	7
No	0
Maybe	0

Question 2: How are you actively managing soil erosion on your farm? (Please check as many as apply to your situation)

	Responses (out of 7)	percentage
Establishing/maintaining field windbreaks	4	57
Utilizing cover crops to reduce soil loss by wind erosion	3	43
Using cropping practices (e.g. conservation tillage)	7	100
Erosion Control Structures	1	14

Question 3: Of these two, cover crops or windbreaks, which one is more important to you in managing windblown soils on your farm?

	Response (out of 7)
Cover Crops	3
Windbreaks	4
Neither	0

Question 4: Are there any vegetables (shrub or tree) windbreaks on your property? (Check all that apply)

	Response (out of 7)	percentage
Surrounding each field	1	14
Surrounding some fields	2	29
Only on the farm property lines	2	29
Only surrounding the home/barns	2	29
Both around the barns and fields	2	29
Don't know/Not Applicable	0	0

Question 5: Do you only manage windbreaks on properties you own?

	Response (out of 7)
Yes	7
no	0

Question 6: If you have windbreaks on the farm, approximately how old are they?

- 2-20
- 10
- 10-30
- 17
- 20
- 25

Question 7: Please provide us with some reasons why windbreaks were planted on your farm? (Please Check as many as apply)

	Response (out of 7)	percentage
Crop yield improvements	3	43
Soil conservation (Erosion control)	6	86
Snow management	3	43
Provide wildlife habitat	2	29
To be used for firewood, pests etc.	1	14
Generate other non-timber revenue (e.g. supplemental crops)	0	0

Question 8: Do you think maintenance of windbreaks is important (Check one)

	Response (out of 7)
Yes	5
No	0
Not sure	2

Question 9: What type of activities do you think are necessary to maintain a healthy windbreak? (Please check the boxes that apply)

	Response (out of 7)	percentage
Tree trimming and thinning	4	57
Removal of dead or diseased trees	7	100
Replanting	4	57
Fencing	0	0
Spraying for tree pests	2	29
Other Please Specify	1 (Trim to keep from entering field area)	14

Question 10: Have any field windbreaks (or portions thereof) been removed from the farm you now operate? (Check one)

	Response (out of 7)
Yes	0
No	7
Don't know	2

Question 11: Please tell us for what reasons the field windbreak(s) was removed? (Check the boxes that apply)

	Response (out of 7)
Preparation for new windbreak	0
Windbreak competing with crops	0
No economic value of land in windbreak	0
Conflict with irrigation development	0
Caused excessive snow accumulation on roads	0
Consolidation of additional fields	0
Other Please Specify	0

Question 12: What incentives do you think farmers would find helpful to establish new windbreaks?

	Response (out of 7)	percentage
Financial (Cost share)	7	100
Technical information Workshops	4	57
Other Please Specify	3	43

Question 13: How likely is it that you will establish new field windbreaks on your farm?

	Response (out of 7)
Very Likely	1
Likely	6
Not Likely	0

Question 14: Would you like assistance with the layout and design of a field windbreak that could include features to provide new revenue streams such as intercropping between windbreaks?

	Response (out of 7)
Yes	3
No	2
Ask me another time	2

Question 15: What commodities do you have on your farm? (Check all that apply)

	Response (out of 7)	percentage
Cash crops - no till	5	71
Cash crops - conventional till	4	57
Cash crops - carrots, onions, and other vegetables	0	
Livestock	4	57
Other Please Specify	1	14

Question 16: What is the size of the property you farm?

- 300
- 450
- 90
- 300
- 350
- 180
- 300

Question 17: Any other suggestions you would like to make would be appreciated.

- Anything that can be done to make the windbreaks easy for the farmer will see more go in. Our windbreaks were established with assistance from the Upper Thames when the SWEEP program was active. They helped us to plant the windbreaks.

Southwest Diagnostic Farm Days Field windbreak survey and associated covering letter

July 04, 2011

RE: Farm Windbreaks Survey

Thank you for participating in today's windbreak presentation. This year, OMAFRA and its partners are exploring new ways to establish windbreaks in the province by asking farmers about their experiences using field windbreaks. The survey we are asking you to fill out for us today is part of a larger windbreak research project in the Nottawasaga Valley Conservation Authority to improve water quality of Lake Simcoe.

A similar windbreak survey is being administered by the NVCA to the local farming community with support from the Ontario Ministry of Agriculture, Food and Rural Affairs(OMAFRA). This coming fall two workshops on windbreaks in the Lake Simcoe area are planned where new windbreak designs will be shared and discussed.

We plan to use the results from all our farmer windbreaks surveys to help focus Ontario-specific windbreak research and extension programs delivered by OMAFRA, Conservation Authorities and various extension staff. The survey information being collected is for general research purposes only. Your answers will be kept confidential.
Your time and help is greatly appreciated.

If you have any questions, please feel free to contact one of the members of the Windbreak Research Team below.

Windbreak Research Team:
Peter Roberts, OMAFRA, 519-826-3578; peter.roberts@ontario.ca
Deborah Brooker, OMAFRA, 519-826-4109;deborah.brooker@ontario.ca
Ryan Post, Hydrogeologist, Nottawasaga Valley Conservation Authority, 705-424-1479 ext 249; rpost@nvca.on.ca

FIELD WINDBREAK SURVEY

1. .**Are you actively managing soil erosion on your farm?(CHECK ONE (√)**

   ☐ Yes ☐ No ☐ Not Sure

2. **How are you actively managing soil erosion on your farm? (PLEASE CHECK(√)as many as apply to your situation**

   ___ Establishing/maintaining field windbreaks

   ___Utilizing cover crops to reduce soil loss by wind erosion

   ___ Using cropping practices (e.g conservation tillage)

   ___ Erosion Control Structures

3. **Of these two, cover crops or windbreaks, which one is more important to you in managing windblown soils on your farm?**

   ☐ Cover Crops ☐ Windbreaks ☐ Neither

4. **Are there any vegetative (shrub or trees) windbreaks on your property? Check (√) all that apply**

   ___ Surrounding each field

   ___ Surrounding some fields

   ___ Only on the farm property lines

   ___ Only surrounding the home/barns

   ___ Both around the barns and fields.

   ___ Don't know/Not Applicable

5. **Do you only manage windbreaks on properties you own?(PLEASE CHECK ONE (√) CATEGORY)**

   ☐ **Yes** ☐ **No**

6 **If you have windbreaks on the farm approximately how old are they? Please specify in Years_____(Windbreak age in Years**)

7. **Please provide us with some reasons why windbreaks were planted on your farm. ?(PLEASE CHECK As many as apply(√)**

   ☐ Crop Yield Improvements
   ☐ Soil Conservation (Erosion Control)
   ☐ Snow Management
   ☐

☐ Provide Wildlife Habitat
☐ Trees to be used for firewood, pests etc.
Generate other non-timber revenue (eg. Supplemental crops)
☐

8. Do you think maintenance of windbreaks is important? (Check (√) ONE)?

☐ Yes ☐ No ☐ Not Sure

9. What types of activities do you think are necessary to maintain a healthy windbreak? **Please check (√) the boxes that apply.**

☐ Tree trimming and thinning
☐ Removal of dead and diseased trees
☐ Replanting
☐ Fencing
☐ Spraying for tree pests
☐ Other. Please

Specify_____

_____

10. Have any field ***windbreaks*** (or portions thereof) been ***removed from the farm*** you now operate? **Check (√) ONE**

☐ Yes ☐ No ☐ Don't know

11. Please tell us for what reasons the field windbreak(s) was removed? (**Check (√)** the boxes that apply.

Preparation for new windbreak	
Windbreak competing with crops	
No economic value of land in windbreak	
Conflict with irrigation development	
Caused excessive snow accumulation on roads	
Consolidation of added fields	
Other, Please Specify	

12. What incentives do you think farmers would find helpful to establish new windbreaks?

☐ Financial (Cost Share)
☐ Technical Information

☐ Workshops
☐ Other
If Other Please Specify:----------

---

13. How likely is it that you will establish new field windbreaks on your farm?

Please Check (√) one choice.

☐ Very Likely ☐ Likely ☐ Unlikely

14. Would you like assistance with the layout and design of a field windbreak that could include features to provide new revenue streams such as intercropping between windbreaks?

☐ Yes ☐ No ☐ Ask me another time

16. What commodities do you have on your farm? (CHECK (√) ALL THAT APPLY)

___ Cash Crops – no till
___ Cash Crops – conventional till
___ Cash crops – carrots, onions, and other vegetables
___ Livestock
____Other, please specify _____

17. What is the size of the property you farm? Please specify in acres
_____(acres)

Thank you for the time you have taken to complete this survey. Your time is very much appreciated. *This survey was adapted from thesis work of Kim Tomczak, University of Nebraska, 2009.

Appendix 4: Windbreak Reference Materials

Although not exhaustive, the following is a list of references of various wind break/shelter belt resource materials that have been released in various jurisdictions in North America which can be used to aid in the material development for the multifunctional shelter belt project. The bibliography lists general references, as well as those relating to Best Management Practices and contains the links for each respective document.

Agroforestry Development Centre http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1186590611493&lang=eng

Break Wind, make money
Conservation Ontario, Ontario, and OSCIA
http://www.ontariopork.on.ca/portals/0/Docs/Research/Environment/09-23-2009_windbreaks_bro_en.pdf

Windbreak/Windbreak Establishment – Code 380
Natural Resources Conservation Service, Conservation Practice Standard, NRCS – Minnesota August 21, 2009,
http://efotg.sc.egov.usda.gov//references/public/MN/380mn.pdf

Windbreak/Windbreak Establishment
Natural Resources Conservation Service (Minnesota), Revised April 2003
http://nrcslearn.sc.egov.usda.gov/AglearnCS/consforestry/content508/supporting_material/JobSheet-WindbreakEstablishment-Revised.pdf

Windbreak/Windbreak Renovation
Natural Resources Conservation Service – Conservation Practice Standard, NRCS – Minnesota November 1998 Conservation Practice,
http://efotg.sc.egov.usda.gov//references/public/MN/650mn.pdf

Windbreaks/Windbreaks as Wildlife Habitat,
Natural Resources Conservation Service – South Dakota, April 2004,
ftp://ftp-fc.sc.egov.usda.gov/WHMI/WEB/pdf/SDwindbreakwindbreak.pdf

Ecological Development and Function of Windbreaks in Temperate North America
USDA Forest Service4 National Agro Forestry Centre, USDA Forest Service / UNL Faculty Publications, University of Nebraska – Lincoln Year 2008, Bentrup, G., Brandle, James R., Mize, C. W., Schonebergez, M.M.,
http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1041&context=usdafsfacpub&sei-redir=1#search="Ecological+Development+and+Function+of+Windbreaks+in+Temperate+North+America+nebraska"

Windbreak Management
University of Nebraska, Brandle, James R., and Natural Resources Conservation Service (USDA) Stange, Craig, No Date,
http://www.nfs.unl.edu/documents/windbreakmgmt.pdf

Windbreak Renovation
University of Nebraska, Brandle, James R., Wilson, Jon and Utah State University, Kuhns, Mike, Natural Resources Conservation Service (USDA), Stange, Craig, No Date, ,
http://www.nfs.unl.edu/documents/windbreakrenovation.pdf

Windbreaks and Wildlife
University of Nebraska, Beck Mary M., Brandle, James R., Johnson Ron, No Date,
http://www.nfs.unl.edu/documents/windbreakwildlife.pdf

Field Windbreaks
University of Nebraska, Brandle, James R., Hodges, Laurie, No Date
http://www.unl.edu/nac/morepublications/ec1778.pdf

Windbreaks for Fruit and Vegetable Crops
University of Nebraska, Brandle, James R., Hodges Laurie, No Date
http://elkhorn.unl.edu/epublic/live/ec1779/build/ec1779.pdf

Windbreaks for Livestock Operations
University of Nebraska, Brandle, James R., North Dakota State University Johnson, LaDon, Quam, Vernon, Soil Conservation Service, Wright, Bruce, No Date
http://www.unl.edu/nac/brochures/ec1766/index.html

Windbreaks for Rural Living
University of Nebraska, Boes, Teresa K., Brandle, James R., Soil Conservation Service, Wright, Bruce, No Date
http://www.nfs.unl.edu/documents/windbreakruralliving.pdf

Windbreaks for Snow Management
University of Nebraska, Forestry Fisheries and Wildlife, Brandle, James R., Nickerson H. Doak, Soil Conservation Service, Wright, Bruce, No Date
http://www.unl.edu/nac/morepublications/ec1770.pdf

Why Plant a Windbreak , Ohio Department of Natural Resources,
http://www.ohiodnr.com/portals/18/landowner/pdf/windbreaks_guide.pdf

Windbreaks for Wildlife Ohio
Ohio State University Extension Fact Sheet and School of Natural Resources, The Ohio State University, Rodewald, Amanda D., PhD., Santiageo Melissa J.
http://ohioline.osu.edu/w-fact/0016.html

Windbreak/Windbreak Implementation on the Farm
University of Missouri, The Centre for Agroforestry School of Natural Resources
http://agebb.missouri.edu/commag/windbreak/EdMaterials.htm