CONSERVATION PRACTICE SPECIFICATION
Windbreak/Shelterbelt Establishment – 380

This document provides conservation planners with the parameters, procedures, and requirements for developing site-specific plans for windbreak and shelterbelt systems for a variety of purposes. Where appropriate, specific references are cited to provide detailed information needed for a successful design. Note: FOTG refers to NRCS' Field Office Technical Guide.

The supporting documents needed to complete a windbreak design are:

- Windbreak Suitability Groups are found in county specific Interpretive Tables in FOTG – Section II – Soil Information.
- Tree Care and Management is located in FOTG Section I – Reference Subjects – Windbreaks and Woodland.
- Expected 20-Year Tree Heights by Windbreak Suitability Groups is located in FOTG Section II – Windbreaks and Forest.
- Tree and Shrub Characteristics table is located in FOTG Section I – Reference Subjects – Windbreaks and Woodland.

No matter the purpose of the planting, most plantings are simply modifications of two basic windbreak/shelterbelt designs.

1. Building site or livestock shelterbelts, which are multiple row plantings, designed to protect farmsteads, feedlots or other building sites. They may be designed to protect livestock or other animals wherever that protection is needed.
2. Field windbreaks that are single- or multiple-row plantings designed to prevent erosion, protect crops and roads, to harvest snow, to provide noise or visual screens or to supplement building site or livestock shelterbelts.

WINDBREAK SUITABILITY GROUPS

To determine which trees will grow satisfactorily on which soils and to determine the expected heights after 20 years, refer to Windbreak Suitability Groups found in county specific Interpretive Tables in FOTG – Section II – Soil Information for each soil component and Expected 20-Year Tree Heights, respectively.

WOODY PLANT STOCK

To determine which type of plant stock is appropriate for windbreak/shelterbelts refer Tree Care and Management, page 2.

STOCK STORAGE HANDLING AND CARE REQUIREMENTS

To determine proper stock storage, handling and care requirements, refer to Tree Care and Management pages 3-4.

SITE PREPARATION

To determine an appropriate method of site preparation, refer to Tree Care and Management pages 4-8.

PLANTING

To determine an appropriate planting technique for a particular stock used in a windbreak/shelterbelt system, refer to Tree Care and Management pages 8-11.

ORIENTATION, LOCATION, SETBACKS

When designing a windbreak, consider the effects of the surrounding topography and land management on the ability of the windbreak to perform its function. Conversely, consider the positive

and potentially negative impacts the windbreak may have on the surrounding land uses. A sample of the items to consider include: areas of snow drifts, water runoff from melting snow, water erosion potential, stifling of air flows during the summer, visibility hazards, ice blockage of drains, etc.

Orientation

Wherever possible the plantings should be oriented perpendicular to troublesome winds. Since winds rarely blow from the same direction all the time, base the design on the predominant wind direction during the time that the area needs protection. For snow control or harvest purposes and for winter livestock or farmstead protection in North Dakota, predominant winter winds come from the northwest, except in the Red River Valley where they generally come from the north-northwest.

However, not all damaging storms come from the predominant wind direction. Individual sites can vary considerably. Late season snowstorms could plug a road from a southeast direction or fragile crops could be blasted by a hot, dry wind from the southwest. Determine what needs protection and from where the damaging winds originate and locate the windbreak/shelterbelt accordingly.

Locations

All Windbreaks

Windbreak design is often based upon the downwind protection provided by the windbreak at 20 years of age. This distance is measured in multiples of windbreak height at 20 years and is referred to as H. H = height of tree or shrub, measured at 20 years unless otherwise noted. For certain situations H may be multiplied by values other than 10. (15-20 H for a snow spreading windbreak.)

On sloping land they should be located as near to the contour as possible to reduce erosion risks and water loss.

In western North Dakota or on droughty soils consider locating windbreaks to allow the diverting of water from adjacent areas into the windbreak for supplemental moisture.

Windbreaks to trap snow for supplemental water in stock ponds should be located in a position to dump the majority of the snow close to, or in, the stock pond or major tributaries. Avoid tree species such as cottonwood, willow etc. that are heavy water users. Windbreaks for this purpose should be as narrow and dense as possible (ex: twin-row conifer or twin-row shrub).

Windbreaks will be positioned to avoid causing visibility problems at road intersections, curves and driveway entrances. Generally speaking, the trees or shrubs at maturity should not spread into the right-of-ways of roads. Refer to Tree and Shrub Characteristics for the spread (width) of plants at maturity.

Maximum snow deposition will usually occur within a zone located 2-5 H from the most windward dense row. This relationship holds true for dense windbreaks as well as porous windbreaks. Differences in snowdrift depth are more pronounced on more dense windbreaks.

Tree and shrub plantings on native range and/or wetlands is permitted only after alternative treatments have been evaluated and then only to protect infrastructure (building sites, roads, livestock).

Primary Windbreaks

Windbreaks primarily for wind protection and snow control are usually located to the north and west of the area needing protection.

Windbreaks needed primarily for wind protection of crops shall be located in a manner that places them between the troublesome winds at the critical stage of the crop needing protection.

Snow traps located 50-150’ upwind of the primary windbreak can increase effectiveness of the rest of the windbreak system by reducing the amount of snow needing to be stored in the primary windbreak. (MLRA 55 and 56).

Trapping of snow outside the primary windbreak in Major Land Resource Areas 53, 54, and 58 should be planned with caution, since the removal of snow moisture from the root zone of the main windbreak may adversely impact the life and effectiveness of the windbreak.

All areas needing protection should be located within the 10H - 15 H zone on the leeward side of the windbreak. Estimates of 20-year heights of trees and shrubs needed to calculate areas of protection can be found in Expected 20-Year Tree Heights.

Field windbreaks designed for snow spreading may be spaced up to 20 H apart.

Secondary Windbreaks

Secondary windbreaks are located on the leeward sides, usually the south and east, of the area protected by the primary windbreak.

Secondary windbreaks usually consist of shrubs or short trees to stop the rare snowstorm from the south or east while allowing summer breezes to penetrate the protected area.

Setbacks

All Windbreaks

Windbreaks shall be located no closer than 16 feet away from any property line unless a signed agreement between both owners exists that would permit a closer planting.

According to North Dakota Century Code, no trees or shrubs may be placed within 33 feet of a section line unless written permission has first been secured from the county commissioners or township supervisors.

No trees shall be placed within the easement area of overhead transmission lines unless permission has been secured from the appropriate utility company.

As per international treaty, no trees or shrubs shall be planted in a location where the foliage, at maturity, will encroach upon the 20' wide (10' each side) line-of-site vista along the Canada-USA border.

Windbreaks that are adjacent to, or cross, legal and private drainage ways should be set back at least 100' to prevent snow and ice buildup that will restrict spring drainage.

In all cases, if local units of government have established more restrictive setback distances, then the more restrictive regulations will apply.

Primary Windbreaks

For windbreaks north and/or west of the area needing protection, the most windward row must be at least 200 feet from the area to be protected. See Figure 1.

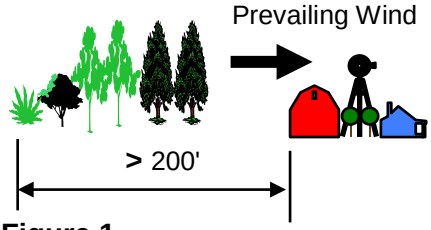

Figure 1

When measuring from roadways, the measurement should begin at the edge of the road surface nearest to the proposed windbreak. See Figure 2. The most windward row of a snow trap can be used for setback measurement purposes. This setback distance also applies to the ends of windbreaks that are perpendicular to roads and areas needing protection.

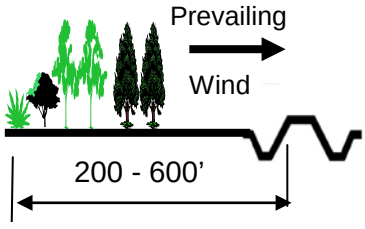

Figure 2

The setback distances may be reduced by 50 feet if topography, healthy field windbreaks upwind, reduced fetch distances, or long term crop management practices can be expected to remove 50

percent or more of the typical snow load before it reaches the main windbreak.

Leeward rows of primary windbreaks, located to the north or west of a road, even with the minimum 200-foot setback to the windward row, should be no closer than 100 feet to the nearest traveled portion of a public road. See Figure 3.

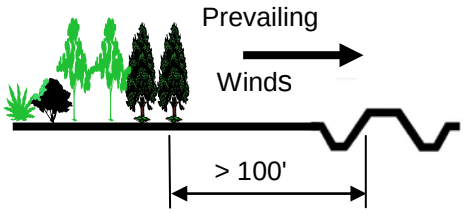

Figure 3

For snow control, windbreaks should not be placed farther from the area needing protection than 35 times the expected 20-year height of the tallest species to be planted or 600 feet, whichever is smaller.

Windbreaks planted to the south or east of roadways shall be located no closer to the road than 5 times (5H) the mature heights of the trees and/or shrubs in order to reduce upwind snow deposition and shading problems. Refer to Tree and Shrub Characteristics for mature plant heights. When measuring from roadways, measurements begin at the portion of the road surface nearest the proposed planting. See Figure 4.

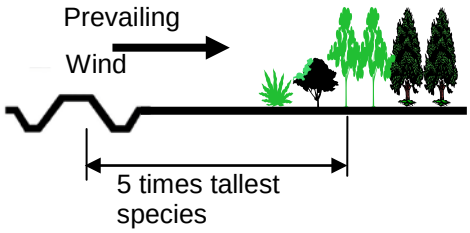

Figure 4

Secondary Windbreaks

In North Dakota, secondary windbreaks are usually located to the south and east of the areas needing protection. Secondary windbreaks should be located far enough away from the area needing protection to allow snow deposition where it won't be a problem and to provide year-round accessibility in and around the area protected.

The inside tree or shrub row in windbreaks on the south and east of areas needing protection shall not be any closer than 100 feet. Where solar gain during the winter is important, windbreaks on the south side of a building site shall be no closer than 3 times the mature height of the tallest plant. Exercise caution in utilizing tall trees in secondary windbreaks that may restrict summer breezes.

WINDBREAK DESIGN

General Information

Windbreak tree species shall be selected that are compatible with the soils on which they will be planted. Refer to the Expected 20-Year Tree Heights, located in FOTG – Section II – Windbreaks and Forest, to determine which plants will grow on which soils. Most soil map units contain small percentages of minor soil components. See Windbreak Suitability Groups by County in Section II FOTG to determine component soils within each map unit. Ensure that the species selected are compatible with these minor components as well. Changes in soil properties within the planting site may require a species change within the row. If there is any doubt, select species appropriate for the most limiting soil condition.

Unless otherwise noted, 20-year plant heights will be used to determine setback distances and the extent of protected areas. Expected 20-year heights of trees and shrubs, under good management, can be found in Expected 20-Year Tree Heights.

Maximum snow depth can be expected within 2-5 H from the tallest tree or shrub row, under normal winter conditions. The deepest part of the snowdrift will be closest to dense windbreaks and will be located progressively farther away from the windbreak as windbreak density decreases.

Zones of protection will vary, depending upon density and height of the windbreak. Generally, the denser the windbreak the greater the wind speed reduction and the smaller the zone of protection.

No more than two rows in any windbreak system shall be of the same species unless site conditions restrict the number of available species.

Ends of windbreaks should extend at least 200' past the area needing protection to account for end effects and to allow for shifts in wind direction.

If there is insufficient space or suitable soils to install the normally required minimum number of rows, a narrower windbreak is permissible, though a minimum of 1 shrub row and 2 deciduous tree rows- or 2 coniferous rows- shall be established.

Design Purpose

All Windbreaks

Design living snow fences and farmstead and feedlot windbreaks, for circumstances worse than average. I.e.: Don't scrimp on setbacks, number of rows or diversity of species.

Field windbreaks can be designed for average conditions for the time of year during which protection is needed.

The minimum number of rows for a primary windbreak will vary, depending upon the purpose of the planting. Refer to Table 1 for spacings to achieve targeted within-row densities.

Any design of one or more rows is acceptable for a secondary windbreak.

For Snow Control

Two or more rows of deciduous trees and/or non-suckering shrubs; or one or more rows of conifers and/or suckering shrubs. Multiple rows of different species are strongly encouraged. Refer to Table 1 for within-row and between-row spacings.

For Snow Spreading on Cropland, or Pastureland

Suckering shrubs, spruces, junipers, cedars or arborvitaes are not suitable.

The windbreak shall consist of one row of non-suckering shrubs, deciduous trees, larches or pines. Multiple rows of pines or shrubs may become too dense to effectively spread snow. Extra maintenance is required when relying upon a single row to ensure that no gaps develop in the windbreak.

Lower limbs may be pruned or plants thinned, especially on pines or shrubs respectively, to increase snow distribution, reduce drift height and subsequent delays in field operations near the windbreak. Refer to Table 1 for within-row and between-row spacings.

For Erosion Control

One or more rows of deciduous shrubs, trees or conifers are appropriate for erosion control windbreaks. See Table 1 for in-row spacings to achieve desired density. Use wind erosion formulas to determine windbreak spacing across a field to achieve desired soil protection. For some sensitive crops, any erosion, even if below soil loss limits, may be damaging to the crop. Windbreak systems shall be designed to limit the maximum of soil erosion to, or less than, the amount the planned crop will tolerate. To determine these tolerances, refer to table 502-4 – “Crop tolerance to blowing soil” in part 502 of the National Agronomy Manual. The National Agronomy Manual is located in FOTG – Section I – Erosion Prediction.

For Traditional Crop Protection

Plant one or more rows of deciduous shrubs, trees or conifers. Use 10 times the 20-year height, measured parallel to the problem wind to determine the protected area. This measurement- when combined with the results of the most current wind erosion calculations- will yield the appropriate windbreak spacings. To increase farmability between windbreaks, reduce the spacings between windbreaks to those of even tool bar widths. Increased windbreak density increases crop protection benefits but slightly reduces the overall area receiving benefits. Be alert to how increased density for

crop protection may result in delayed spring fieldwork because of narrow, deep snowdrifts. Refer to Table 1 for within-row and between-row spacings.

For Specialty Crop Protection

Usually, more than one row of non-suckering shrubs or deciduous trees will be needed to provide adequate wind protection. One or more rows of suckering shrubs or conifers may provide the desired protection. Refer to Table 1 for within-row and between-row spacings. Ensure that the planting has adequate density close to the ground. Assume that a planting achieving 60-80 percent density will reduce soil loss to zero within the 10H protective zone.

Depending upon requirements of the crop, additional secondary windbreaks may be needed to provide protection during critical crop stages.

Note: Be alert to creating frost pocket conditions by entirely encircling the crop field or by placing windbreaks downslope from specialty crop fields. Frost pocket conditions can be lessened by pruning the lower 3-4 feet of branches from trees as they mature to prevent cold air from concentrating on sensitive crops; however this will also reduce crop protection provided by the windbreak.

Livestock and Building Site Protection

6 rows of trees and shrubs, minimum, for Major Land Resource Areas (MLRA) 53, 54, 58.

8 rows of trees and shrubs, minimum, for MLRA 55, 56.

Assuming that proper setback distances have been observed in the design, then the number of rows in a livestock/building site windbreak may be reduced by one for each of the following that occurs:

- Spruce, juniper, redcedar, or a suckering shrub is planted in the most windward row.
- An effective field windbreak system is already established with the most leeward row no more than 300' from the proposed windbreak.
- A snowtrap of juniper, redcedar, closely spaced shrubs, or a twin-row high-density deciduous tree or shrub planting, is located 50-100' windward of the proposed windbreak.

Refer to Table 1 for within row and between row spacings.

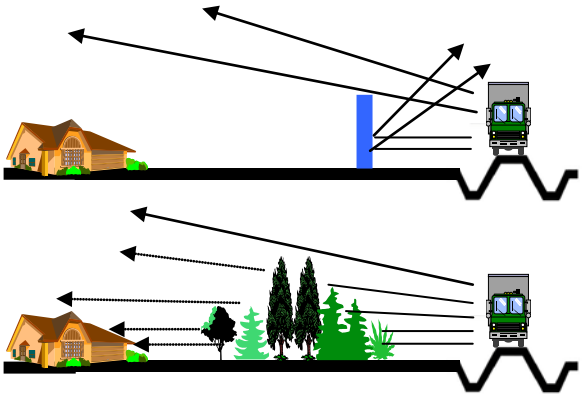

Figure 5: How Sound Barriers Work

For Noise Barriers

Noise barriers reduce noise by deflecting the noise away from the observer, by absorbing some of the noise before it reaches the observer or both. See Figure 5. They are most effective when they can be placed as close as possible to the noise source. Barriers should be placed within 50-80 feet of the nearest traffic lane. See Figure 6.

The amount of noise reduction attained is dependent upon the type of surface between the observer and the source over which the noise passes as well as the width, setback distance and composition of the noise barrier. Vegetation, especially standing vegetation, reduces and attenuates noise better than bare or hard surfaces. Where year-round noise reduction is desired, conifers should constitute the majority of the planting. See Table 1 for spacings.

Deciduous trees or shrubs can be used where noise reduction is needed only during the growing season. See Table 1 for spacings.

Tree and/or shrub barriers, when combined with landforms, either earthen or constructed, show greater benefits in noise reduction than do landforms alone or trees alone. See Figure 7.

When landforms or constructed barriers are incorporated into the design they should be as tall as the vehicle or object making the noise and may be constructed of soil or other materials. If constructed of soil the landforms should be planted to tall grasses, shrubs or trees for maximum effectiveness.

Barriers for reducing high-speed truck noise must be at least 75' wide if only trees or shrubs are used or at least 50' wide if vegetation is combined with a landform.

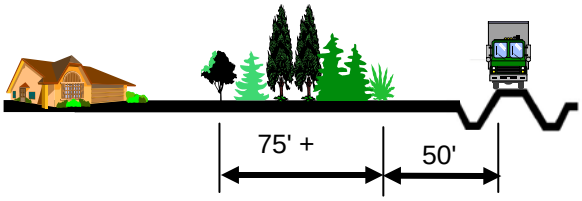

Figure 6: Vegetative Sound Barrier

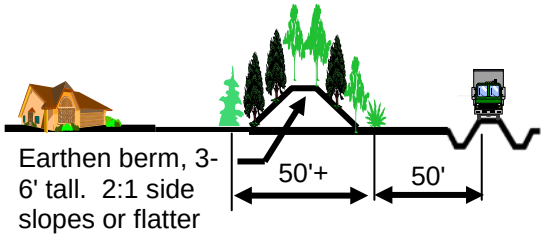

Figure 7: Vegetative Noise Barrier and Landform

Barriers for reducing moderate noise levels (cars) must be at least 40' wide if only trees or shrubs are used or at least 20' wide if vegetation is combined with a landform.

Noise barriers must be twice as long as the distance from the observer to the noise source.

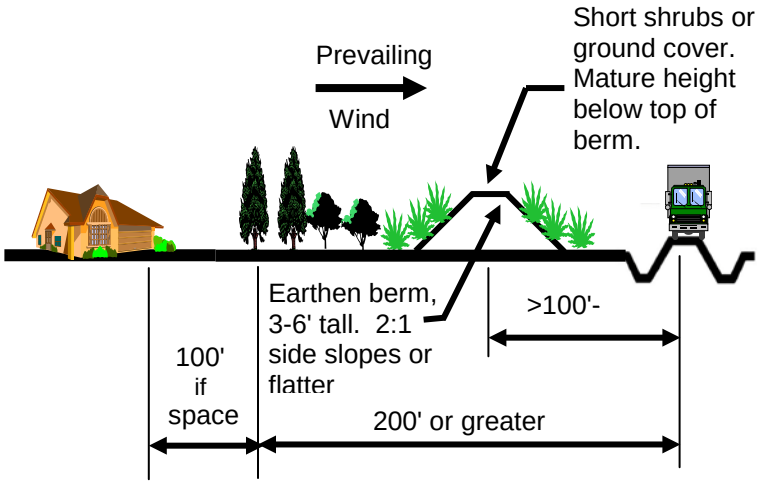

Figure 8 Where Sound <u>and</u> Snow are Problems

No matter how severe the noise, noise barriers shall not be positioned where the barriers will cause snow deposition or drifting on the road sufficient to create a safety hazard to the traveling public. For many of these situations a living snow fence system is often needed upwind from the observer, thereby reducing the amount of snow that could cause a problem. See Figure 8 for one alternative to address this problem where there is no room to establish a living snowfence system upwind from the observer.

Information for designing noise barriers was obtained from an article by David I Cook and David Van Haverbeke in the Journal of Soil and Water Conservation, November-December 1972, pages 259-261.

<u>For Visual Screens</u>

Rows of trees or shrubs shall be placed between the observer and the undesirable view needing to be screened. Plantings shall be at least one row of conifers or at least 3 rows of deciduous trees or shrubs or a combination of deciduous and coniferous plants. Increasing the number of rows in the planting will increase the effectiveness in blocking unsightly vistas.

Often visual screens will be designed with species that are aesthetically pleasing to the observer or landowner. Refer to <u>Tree and Shrub Characteristics</u> for species-specific information.

Plantings may be established immediately adjacent to the sight to be screened, which allows more open spaces around the observer. The plantings may be placed closer to the observer to site-specific needs or landowner objectives. See Table 1 for in-row and between-row spacings.

Where visual screens may cause snow problems on roads or building sites, the more restrictive setback distances for snow control must be followed.

For Wildlife

When the primary purpose of a planting is to improve conditions for wildlife, it is best to refer to the Upland Wildlife Habitat Management-645 Standard for specific details appropriate for the wildlife specie(s) of interest. All conservation practices are located in FOTG – Section IV – Conservation Practices. However, the designs of windbreaks for other purposes can be modified to make the practice more beneficial to wildlife while still addressing the original windbreak purposes. Considerations for improving the wildlife value of windbreaks include, but are not limited to:

1. Provide dense areas (thickets) of suckering shrubs or conifers, especially spruce and juniper for winter thermal protection.
2. Choose a variety of plants that will provide food throughout the growing season, especially during mid and late winter. Refer to Tree and Shrub Characteristics for individual species value as a food source.
3. Using tall grasses, standing corn, trees or shrubs, establish a snow trap 50-100 feet upwind to prevent snow from covering the food sources and shelter areas.
4. Add additional rows that provide food or cover on the lee side of the planting.
5. Add a secondary windbreak to protect food and cover from storms from the south or east.
6. Connect isolated plantings by providing travel corridors of 3-4 rows of trees/shrubs between established woody plantings.

For Boundary Delineation

Adhere to all appropriate Setbacks, All Windbreaks, on page 3 of this document when using trees or shrubs to delineate property boundaries.

When using trees or shrubs to delineate field boundaries, be aware of the impact that the mature plant might have on toolbar spacings, machinery operation, or adjacent fences. Avoid creating a future nuisance for the landowner.

Any within-row spacing is appropriate for this purpose. See Table 1. Be aware of how different spacings affect snow distribution and depth, timeliness of field operations, summer breezes, crop protection, moisture harvest, etc.

Boundary plantings can be made more valuable for wildlife by adding additional rows, alternating compatible species within the row, and/or using a variety of plants valuable to wildlife. See Table 2.

For Reducing Chemical Drift

Windbreaks reduce chemical drift hazards in two ways - by reducing the wind velocities across the field where the chemicals are applied and by intercepting chemicals that have moved off site onto the leaves, twigs, and bark of the windbreak plants.

The minimum requirement for this purpose is one row of shrubs, deciduous trees or conifers. Use the appropriate within-row spacing found in Table 1. Where appropriate, use the tallest trees appropriate for the site. Tall trees can intercept more of the laterally moving air mass. Multiple rows of tall trees provide additional benefits since they provide more surface area that can intercept drift.

When installing a system of belts to reduce drift, space each belt at 10 times the expected 20-year tree height. Spacings between belts may be decreased downward to fit even multiples of toolbar widths.

Encourage landowners to use methods and machinery that minimize drift, thereby reducing the amount of chemical moving offsite that must be trapped by the windbreak.

The most difficult part of designing windbreaks for reducing chemical drift is determining what species of tree or shrub will be resistant to the chemical drift 20 years from now. Based on nearly 50 years of herbicide application in North Dakota, phenoxy-type herbicides have been the most damaging to trees. Conifers are most resistant to these types of herbicides, except during periods of rapid, succulent growth.

For Irrigation Efficiency

Windbreaks can improve irrigation efficiency by reducing evaporation at the sprinkler head, reducing evaporation from the plants and soil surface and by reducing transpiration through the plant. Plantings of tall trees just outside the arc of the sprinklers can provide some of the benefits listed, as long as they intercept the troublesome winds.

Another way to address irrigation efficiency is by installing a system of narrow shrub rows that are short enough to allow the sprinklers to pass overhead. These shrub rows can reduce transpiration from the growing crop and provide a microclimate that yields greater production. Preliminary data would indicate that economically the shrub rows would use about the same amount of water that would be saved by the growing crop. Benefits to the crop primarily accrue through stress reduction on the growing crop, protection during critical stages, and erosion reduction.

Aesthetics

Aesthetics are in the eye of the beholder. Use any of the spacings listed in Table 1. Be alert to the effects the windbreak will have on snowdrift locations and depths; alterations of airflow; impacts on visibility, especially at roads; and maintenance requirements of the planting design.

Refer to Tree and Shrub Characteristics for individual species characteristics.

Carbon Storage

Carbon sequestration can be realized through several different mechanisms; cessation of soil tillage, accumulation of carbon in roots and upper tree material, and accumulation of a duff layer. Generally speaking, maximum carbon sequestration can be expected through:

- Close row spacings maximizing plants per acre without unduly causing plant stress that would lead to early mortality. Use the minimum between-row and within-row spacing from Table 1. When different species require different spacings, use the larger of the minimum spacings.
- Establishing long-lived trees.
- Planting trees that will grow large with extensive and deep root systems.
- Harvest of woody material for lumber or fossil fuel substitution.

For maximum carbon storage, minimize amount of tillage within the planting to that necessary for establishment.

For long-term carbon sequestration, establish and maintain adequate firebreaks to prevent catastrophic loss of the planting.

Composition

For sustainability and long-term effectiveness, try for a diversity of species within the planting, and where compatible with plant forms and owner objectives, within the row. Refer to table 2 for acceptable plant alternation schemes.

At a minimum, no more than two rows within any windbreak system shall be of the same species, unless site conditions limit the number of available species.

For multirow plantings, consider at least one or more rows of conifers.

Often a single species will be planted in each row. Generally, this makes subsequent maintenance and renovation easier. However, single-row, single-species plantings are considerably more prone to failure from drought, disease, and/or insects.

Mixing compatible species within the row can reduce the severity and spread of some insect and disease infestations. Refer to Table 2 for acceptable plant alterations. Aside from potential benefits, such mixing will usually complicate the management of the windbreak.

Appropriate selections of species and spacings can allow a planting to meet multiple purposes at the same time.

For most situations a shrub or conifer will be used in the most windward row of a multiple row planting to provide additional snow (moisture) for the growing plants within the planting and to "park" the snowdrift in an area that is out of the way.

Species selection that allows for the production of nuts and fruits for human consumption, woody materials such as grape vines for floral arrangements, nutraceuticals, or other agroforestry products are appropriate for windbreaks, where production of these products does not hinder the primary purpose of the windbreak.

Refer to Design Purposes, pages 5-9, for considerations specific to each purpose that may affect composition of the planting.

Design Spacing

In-Row Spacing

Refer to Table 1 for in-row spacing of the appropriate type of plant to meet a particular purpose.

Between-Row Spacing

To provide adequate growing space, between-row spacings shall be at least 1½ times the within-row spacing for each type of plant, or wide enough to meet the minimum square footage per plant, except for twin-row high-density windbreaks. Use the wider determination when two adjacent rows each have different spacings. Ex: When a tree is adjacent to a shrub, use 1½ times the tree spacing. See table 1 for general within-row spacings.

Several species require specific row spacing recommendations due to rapid growth rates and form. Rows of conifers and deciduous trees should not be established within 25 feet of cottonwoods, hybrid poplars, and tree willows nor should they be alternated with these species within the row. Rows of conifers and deciduous trees should not be established within 20 feet of Siberian elm.

Closer spacing can increase disease potential and cause pines to self-prune lower limbs. Between-row spacings can be modified upward to fit machinery widths. Row spacings wider than 30 feet are usually inappropriate for the species suited to North Dakota. Obviously, this prohibition does not apply to the area between twin-row pairs, snow traps, etc.

Wider spacings are permissible and will usually provide better growing conditions for the tree but will increase the time before canopy closure, if closure happens at all. Canopy closure in the eastern part of the State can be fairly effective at controlling unwanted herbaceous vegetation. In the western part of the State, moisture stress and the presence of bromegrass and quackgrass limits the effectiveness of canopy closure as a weed control method.

If spacings must be increased because of landowner desires or to provide adequate growing space, it is best to increase the between-row spacing rather than the within-row spacing. Closer within-row spacing, as recommended in Table 1, will provide quicker closure and more effective barrier to the wind.

Table 1: In-row Spacing by Plant Type for Specific Purposes (feet)

(Assumes vigorously growing, single row of species type listed.)

Purpose	Suckering Shrubs	Non - Suckering Shrubs	Short / Medium Decid-uous Trees	Tall Decid-uous Trees**	Spruce	Junipers Cedars Arbor-vitaes	Larches	Pines
Snow Control / Stoppage, Noise Barriers Carbon Storage 80% + Density	3 – 6	3 - 4	Not with one row	Not with one row	8 - 14	6 - 10	Not with one row	8 -14
Snow Spreading 35 -60% Density	Not Suitable	5 - 8	6 - 10	10 - 16	Not Suitable	Not Suitable	10 - 14	10 - 16
Erosion Control, Intercepting Chemical Drift 40 - 70% Density	4 – 8	4 - 6	6 - 10	8 - 14	8 - 16	6 - 10	8 - 12	10 - 16
Traditional Crop Protection 40 - 70% Density	4 – 8	4 - 6	6 - 10	8 - 14	8 - 16	6 - 10	8 - 12	10 - 16
Specialty Crop Protection, Visual Screens 60 - 80% Density	3 – 6	3 - 4	5 - 8	8 - 14	8 - 12	6 - 10	8 - 12	8 - 14
Livestock Protection 60 - 80% Density	3 – 6	Not with one row	Not with one row	Not with one row	8 - 14	6 - 10	8 - 12	8 - 14
Building Site Protection, Visual Screens 60 - 80% Density	3 – 6	Not with one row	Not with one row	Not with one row	8 - 14	6 - 10	8 - 12	8 - 14
Minimum Square Footage Per Plant*	15	15	80	144	144	144	144	192

* The minimum square footage per plant means that a design using a minimum within-row spacing will often require a wider between-row spacing in order to ensure enough growing space for each plant. Adequate growing space per plant will maintain a healthy, vigorously growing plant, with a reduced chance of disease incidence, and a strong likelihood that lower limbs will be maintained throughout the life of the planting.

** Rows of conifers or deciduous trees should not be planted within 25 feet of cottonwoods, hybrid poplars or tree willows, nor should these plants be alternated within the row.

These within-row and between-row spacings are specific to the varied purposes of windbreaks only. Other forestry practices such as riparian forest buffers and tree/shrub establishment, etc. will likely have different spacing requirements.

Within-Row Plant Alternation

To meet landowner needs, to improve aesthetics or function, or to reduce disease potential, compatible plants may be alternated within the row. Such a planting scheme increases the complexity of subsequent maintenance operations. See Table 2 for acceptable alternations.

Table 2 - Acceptable Plant Alterations Within The Row

	Short Shrubs ≤ 6' tall	Tall Shrubs >6'	Small/medium deciduous trees < 25'	Tall Deciduous Trees ≥ 25'	Pines	Larches * or Spruces	Juniper or Redcedar
Short Shrubs < 6' tall	YES	INSERT	INSERT	INSERT	NO	NO	NO
Tall Shrubs ≥ 6 feet tall	INSERT	YES	INSERT	INSERT	NO	NO	NO
Small Deciduous Trees < 25'	INSERT	INSERT	YES	NO	NO	NO	NO
Tall Deciduous Trees ≥ 25'	INSERT	INSERT	NO	YES	NO	NO	NO
Pines	NO	NO	NO	NO	YES	NO	NO
Larches * or Spruces	NO	NO	NO	NO	NO	YES	YES
Juniper or Redcedar	NO	NO	NO	NO	NO	YES	YES

Legend:

Yes = Using the within-row spacings from Table 1, replace every other plant with another plant of similar size and type. Ex: A green ash windbreak designed with 12 feet between plants could be altered to become a green ash, bur oak, hackberry windbreak with 12 feet between plants

Insert = Using Table 1 above, select the appropriate between-plant spacing for the tallest plant of the intended alternation scheme. (Select the upper end of the spacing range.) Plant the shorter plant midway between the tall plants. Ex: A green ash planting designed with 12 feet between trees could be altered to become a green ash, caragana, green ash, lilac planting with 6 feet between plants.

No = The listed alternation scheme is not acceptable due to incompatible plant characteristics that could affect form, survival, filling in, shade tolerance, disease etc.

Note: When determining whether a species is short or tall, refer to the maximum height listed in Tree and Shrub Characteristics.

***** When alternating larch, ensure landowner is aware that this species loses its needles in the fall. This attribute will result in a windbreak with apparently dead trees throughout the fall and winter.

Specialty Designs

Twin-row, High-density Windbreaks

Each pair of twin rows will be planted to the same species.

Twin-row, high-density windbreaks for snow control/stoppage and livestock/building site protection shall consist of at least three pairs of twin-rows. The most windward row of the most windward pair must be at least 200' from the area needing protection. See Figure 8.

Within-row spacing for each pair of a twin-row, high-density windbreak will generally be the smallest value from Table 1 for the species type to be planted. Spacing between rows within each pair shall be the same as the within-row spacing. See Figure 9. Spacing between paired rows shall be 30-50 feet.

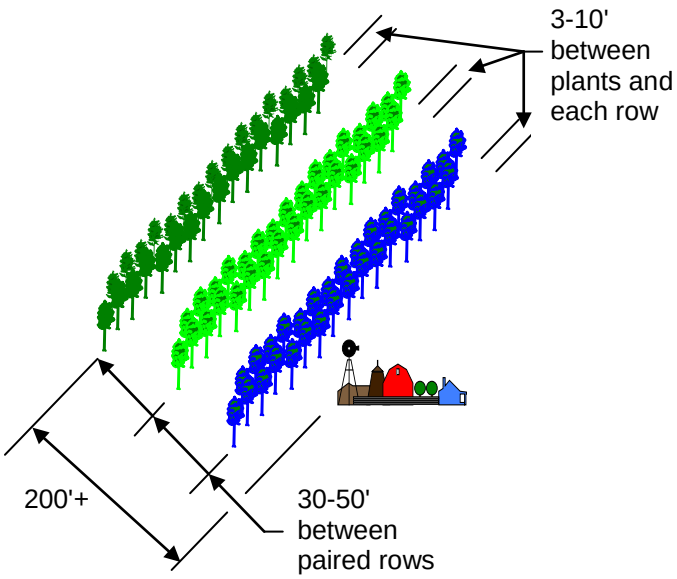

Figure 9: Twin-Row, High-density Windbreak

Windbreak Stubs for Snow Control

To reduce end effects- where existing windbreaks are creating unwanted snowdrifts on roads or other areas needing protection- establish short windbreak stubs. These 300-400' stubs shall consist of 1-3 rows designed as a snow stoppage windbreak (See Table 1) and oriented perpendicular to the problem legs of the existing windbreak. See Figure 10.

For non-cropland sites, the stubs may be planted immediately adjacent to the existing tree rows. With no access gaps, the stubs may be placed as close as 200 feet from the near edge of the area needing protection.

For cropland sites, leave a 50-80 foot machinery access gap between the existing trees and the new trees. When access gaps are a part of the design, the stub rows should be located 400 feet from the near edge of the area needing protection. Access gaps may be incorporated into designs on non-cropland also, based on landowner desires, but the greater setback distance will apply. See Figure 10.

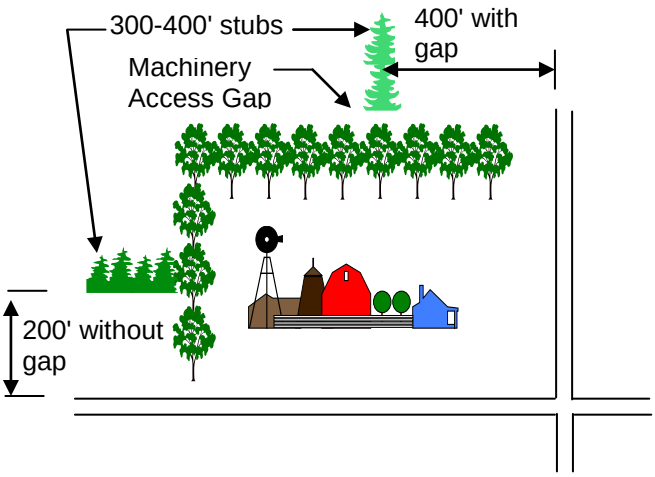

Figure 10: Windbreak Stubs for Snow Control

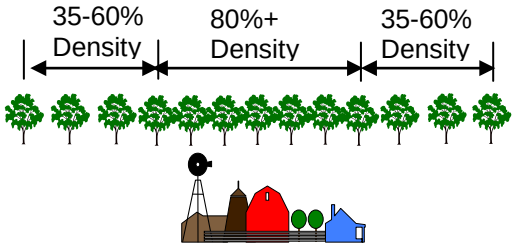

Figure 11: Feathered Windbreak Ends to Reduce End Effect Drifting

Alternative End Effect Reduction

Another way to minimize adverse effects (snow drifts and increased wind velocities) around the ends of dense windbreaks is to change the design of the last 200' from a snow stoppage windbreak to

a snow-spreading windbreak. See Figure 11 for details.

Temporary Windbreaks

For more immediate protection, temporary windbreaks shall be planted at the time the main windbreak is established. Temporary windbreaks will consist of a twin-row high density planting. To be effective, temporary windbreaks must grow at least 1 foot per year faster than the fastest growing species within the main windbreak.

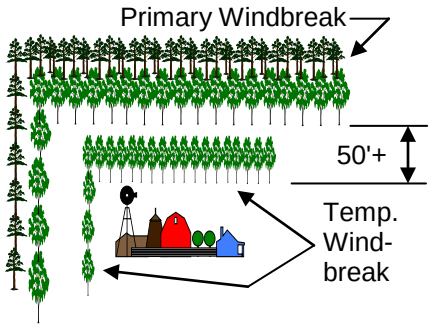

Figure 12: Temporary Windbreaks

Temporary windbreaks may only be used to supplement a properly designed and located primary windbreak. They do not count towards the minimum number of row requirements. See Figure 12 for one possible location.

Locate temporary windbreaks at least 50 feet windward or leeward from the primary windbreak to allow access for harvest or removal. Be alert to how a temporary windbreak will affect snow deposition. Leeward locations will protect the area quicker but may cause problems with snow deposition. Windward locations will eliminate snow problems, but may be too far away to provide protection to the building site any sooner than would the primary windbreak.

Temporary windbreaks are inappropriate if anticipated growth rates of the species in the temporary windbreak do not exceed 2 feet per year on the proposed site. Refer to Tree and Shrub Characteristics for growth rates of individual species. In areas of reduced growth rates, constructed temporary windbreaks may be an appropriate solution.

Effective temporary windbreak designs will often be a twin-row, high-density planting of hybrid poplars or some other fast growing tree or shrub. Once the main windbreak is up and functioning, usually after 10-20 years, the temporary windbreak can be harvested or removed. Properly managed twin-row plantings of poplars can yield a large amount of good quality lumber or firewood.

OPERATION AND MAINTENANCE

Weed Control

To determine an appropriate form of weed control refer to Tree Care and Management, pages 10-14

Replanting

Any tree or shrub that fails within three years should be replaced with a similar plant. Replants shall maintain the intended function of the planting and be compatible with soils and climate. Growth rates of replants (within 3 years) are usually such that little, if any, size difference is noted after 10 years.

After three years a windbreak/shelterbelt shall have at least 85% of the trees planted in a healthy condition with no two adjacent plants missing.

Disease, Insects, Weather and Animals

To determine ways to prevent or control damage due to disease, insects, weather or animals, refer to Tree Care and Management pages 14-16. These pages also list several links that provide more in-depth guidance.

Fire Protection

Windbreaks can be damaged or destroyed by wildfires. In some situations, windbreaks can aggravate the fire risk to a building site. Refer to Firebreak-394 for information on constructing and maintaining effective firebreaks.

OPERATION AND MAINTENANCE FOR LANDOWNERS

To guide landowners in operation and management of their windbreak, provide a copy of pages 11-19 of Tree Care and Management or University of Nebraska pamphlet "Windbreak Management" http://www.ianr.unl.edu/pubs/Forestry/ec1768.htm**.**

OPTIONAL INFORMATION FOR LANDOWNER USE

1. How Windbreaks Work http://www.ianr.unl.edu/pubs/Forestry/ec1763.htm
2. Windbreak Establishment http://www.ianr.unl.edu/pubs/Forestry/ec1764.htm
3. Windbreaks in Sustainable Ag http://www.ianr.unl.edu/pubs/Forestry/ec1772.htm
4. Windbreaks and Wildlife http://www.ianr.unl.edu/pubs/Forestry/ec1771.htm
5. Windbreaks for Rural Living http://www.ianr.unl.edu/pubs/Forestry/ec1767.htm
6. Windbreaks for Livestock Operations http://www.ianr.unl.edu/pubs/Forestry/ec1766.htm
7. Windbreaks for Snow Management http://www.ianr.unl.edu/pubs/Forestry/ec1770.htm
8. Windbreak Management http://www.ianr.unl.edu/pubs/Forestry/ec1768.htm
9. Windbreak Renovation, http://www.unl.edu/nac/brochures/ec1777/ec1777.pdf
10. Field Windbreaks http://www.ianr.unl.edu/pubs/Forestry/ec1778.htm
11. Fruit Bearing Shrubs for Multi-Use Shelterbelts and Orchards
    http://www.agr.gc.ca/pfra/shbpub/fruitshr.htm