Chapter 6: Windbreaks

In this chapter:

- **Defining a Windbreak**
- **How Windbreaks Function**
- **Windbreak Benefits to Soil, Crops and Livestock**
- **Windbreak Design**
- **Productive Windbreaks**
- **Site Preparation, Planting and Maintenance**

Appendix:

- **Non-Agroforestry Uses of Windbreaks:**
  - **o Windbreaks for Homes**
  - **o Windbreaks for Livestock Odor Reduction**
  - **o Living Snow Fences**
  - **o Windbreaks for Wildlife**
- **Success Stories**
- **Economic Incentives**
- **Additional Resources**

This guide is intended to help you design and manage the interactive agroforestry practice of windbreaks. Properly applied on a landscape, a windbreak can enhance and diversify farm income opportunities, improve the environment and create wildlife habitat. By developing an understanding of the interactions between the windbreak (trees, shrubs and grasses) and the adjacent land area, its layout can be most effective at meeting the goals for which it is, or has been, established. By understanding the needs of each of the windbreak's component parts, the windbreak can be managed to best maintain its effectiveness over time, and also sustain its contributions to the farm or ranch.

Agricultural practices benefitting from properly applied windbreaks include:

- Crop production
- Soil conservation
- Livestock and dairy cattle husbandry
- Livestock confinement facilities.
- Nut, fruit, and berry crops

Crops that can be produced from actively managed windbreaks include:

- Nuts, fruits, berries
- Timber, fencepost, firewood
- Christmas trees
- Boughs, cones, wreaths
- Landscape plants
- Shade-tolerant plants such as those grown in the forest farming practice
- Lease hunting opportunities when managed for wildlife benefits

Windbreaks Defined

A windbreak is any barrier (natural or artificial) that reduces troublesome winds by creating a wind shadow to the leeward (down-wind) side. Its major function is to reduce the velocity of the wind. A windbreak must be 2.5 feet or higher to have a significant effect. Many kinds of materials can be used for a windbreak, including trees, shrubs, tall perennial or annual plants (e.g., switchgrass or sunflowers) that will attain a sufficient height to create the desired wind shadow.

The windbreak or shelterbelt practice, uses intensive management for growing trees, shrubs and/or grasses adjacent to other agricultural practices, and consists of one or more rows of closely spaced trees and/or shrubs planted at right angles to the prevailing winds. A windbreak becomes important to the agricultural system by enhancing production, or conservation, as it modifies air movement and wind speeds resulting in microclimatic changes. The terms windbreak and shelterbelt can be used interchangeably.

Seven Windbreak Structural Elements Determine Effectiveness

- Height
- Density
- Orientation
- Length
- Width
- Continuity/uniformity
- Cross-sectional shape

How Windbreaks Function

Windbreak Height. Height (referred to as 'H') is the most important factor determining the downwind area of protection. The windbreak 'H' is the height of the tallest row of trees in the windbreak. The windbreak will reduce wind speed for 2 to 5 times the height of the windbreak (2H to 5H) on the upwind side and up to 30H on the downwind side of the barrier. The area protected is a direct result of the height and density.

Windbreak Density. Density is the ratio of the solid portion of the barrier to the total area of the barrier. Wind flows through the open portions of a windbreak, thus the more solid the windbreak, the less wind passes through. By adjusting windbreak density, different wind flow patterns and areas of protection are established.

Density level is manipulated by choice of plant materials (e.g., deciduous vs. conifer); and plant arrangement. By combining low growing shrubs with medium and tall deciduous trees, dense plant material is provided at three levels (low, middle and upper) of the windbreak during the growing season. However, during the winter, the density would decrease due to the loss of foliage. Consequently, a conifer component would be desirable for year-round protection.

- **Dense (60-80%) =** Maximum wind reduction but short wind shadow
- **Moderately Dense (40-60%) =** Less wind reduction but longer wind shadow
- **Under 40% =** Effective for snow distribution across a field

The term windbreak porosity may also be used to characterize this structural element. The percentage of porosity is the amount of open spaces in the windbreak when viewed perpendicular

to the windbreak. In other words, porosity is the inverse of density, i.e., a 60 percent dense windbreak would be 40 percent porous.

Deciduous 25-35% Density
Open Wind Speed 10 m sec^{-1}

H distance from windbreak	5H	10H	15H	20H	30H
m sec^{-1}	5	6.5	8	8.5	10
% of open wind speed	50%	65%	80%	85%	100%

Conifer 40-60% Density
Open Wind Speed 10 m sec^{-1}

H distance from windbreak	5H	10H	15H	20H	30H
m sec^{-1}	3	5	6	7.5	9.5
% of open wind speed	30%	50%	60%	75%	95%

Multi-Row 60-80% Density
Open Wind Speed 10 m sec^{-1}

H distance from windbreak	5H	10H	15H	20H	30H
m sec^{-1}	2.5	3.5	6.5	8.5	9.5
% of open wind speed	25%	35%	65%	85%	95%

Solid Fence 100% Density
Open Wind Speed 10 m sec^{-1}

H distance from windbreak	5H	10H	15H	20H	30H
m sec^{-1}	2.5	7	9	9.5	10
% of open wind speed	25%	70%	90%	95%	100%

Fig. 1. Wind speed reduction to the lee of windbreaks with different densities.

The degree of density will impact the extent of the area being protected and the magnitude of protection as shown in Figure 1. A solid fence (100% density) provides maximum wind reduction, but the area of wind reduction is shorter than with a dense tree windbreak. The dense windbreak (60-80%) provides a greater area of protection, and the magnitude of wind reduction is as good as the solid structural fence or wall. For the moderately dense windbreak (40-60%), the magnitude of wind reduction is somewhat less but the wind shadow is at its maximum. Once the density drops below 40%, the effectiveness of the windbreak begins to decline. However, the 25-35% density level is very effective for even distribution of snow across a field for moisture management. This density level is not as good for stopping wind erosion.

Windbreak Orientation. Windbreaks are most effective when oriented at right angles to prevailing or troublesome winds, (Fig. 2, below). The best orientation for each windbreak depends on the objectives for the windbreak. A key point to remember is that although the troublesome wind may occur primarily from one direction, it rarely blows exclusively from that direction. As the wind changes direction and is no longer blowing directly against the windbreak, the protected area decreases.

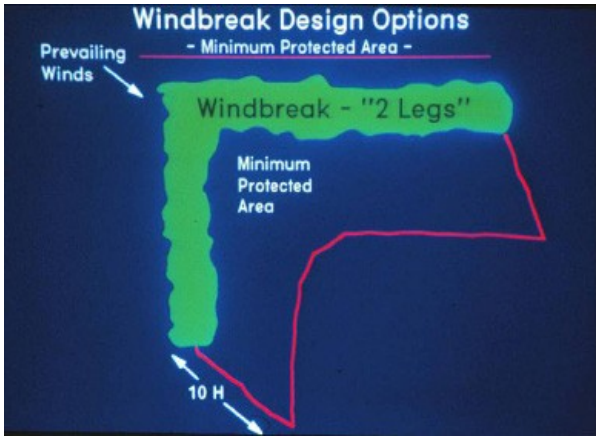


Fig. 2. Windbreak Design Options.

Windbreak Length. Although the height of the windbreak determines the extent of the protected area downwind, the length of a windbreak determines the amount of total area receiving protection. For maximum efficiency, the uninterrupted length of a windbreak should exceed the height by at least 10:1 (i.e., a windbreak 30 feet tall needs to be at least 300 feet long). The ratio reduces the influence of end-turbulence on the total protected area.

Windbreak Width. The width primarily serves as a means to manipulate the desired density of the windbreak. The number of rows, the distance between trees, and species composition are factors controlling windbreak

density. Increasing the number of rows or decreasing the distance between trees increases density and provides a more solid barrier to the wind. A wider windbreak can also increase the value of the windbreak for wildlife and offers opportunities to produce products.

Windbreak Continuity. Continuity influences efficiency. Gaps in a windbreak become funnels that concentrate wind flow, creating areas on the downwind side of the gap in which wind speeds often exceed open field wind velocities. Gaps will decrease the windbreak's effective- ness. Access lanes through a windbreak should be avoided or minimized.

Windbreak Cross-Sectional Shape. Some windbreak guides call for a "hip-roof shape" to assist in "lifting" the wind. However, the cross-sectional shape of windbreaks with equal densities has minimal influence on wind velocities within 10H of the leeward side of a barrier. Be- yond 10H, straight sides provide slightly more protection than slanted sides because more wind passes through the trees and extends the protected area farther to the leeward.

Windbreak Benefits

Windbreaks offer a variety of potential environmental and financial benefits to a farm or ranch enterprise through protection of crops and livestock. The rural community also benefits from improved air quality through wind speed reductions and the physical capture of airborne particulates including dust, smoke, pesticide droplets and odors. Windbreaks also provide aesthetic diversity by adding trees in an agricultural landscape and enhance wildlife habitats and corridors through the addition of tree, shrub and herbaceous cover.

Advantages of Windbreaks

- Enhance crop yield
- Protect soil from wind erosion
- Shelter livestock and crops
- Capture water runoff and nutrients
- Improve irrigation efficiency
- Filter and reduce dust
- Help control odors
- Screen unsightly areas
- Provide wildlife travel corridors and habitat
- Protect structures (homes, outbuildings, roads)
- Reduce noise
- Improve aesthetics

Disadvantages of Windbreaks

- Require more intensive management
- Need specialized equipment for tree/ shrub management
- Remove land from annual crop production
- Financial returns increase gradually as a windbreak grows
- May harbor harmful crop pests, e.g., insects & weeds

Benefits for the Soil

Windbreaks have been widely recognized as a key tool to reduce wind erosion. When wind speed is reduced, the wind erosion process cannot start. Wind erosion can rob land of precious topsoil containing nutrients and organic matter. This loss can lead to reduced productivity and the need to add more nutrients. Wind erosion potential is the greatest when fields are very wide and the soil is bare and smooth. Windbreaks combined with other wind erosion control measures (e.g., reduced tillage, herbaceous wind barriers) create a conservation approach to tolerating wide weather extremes.

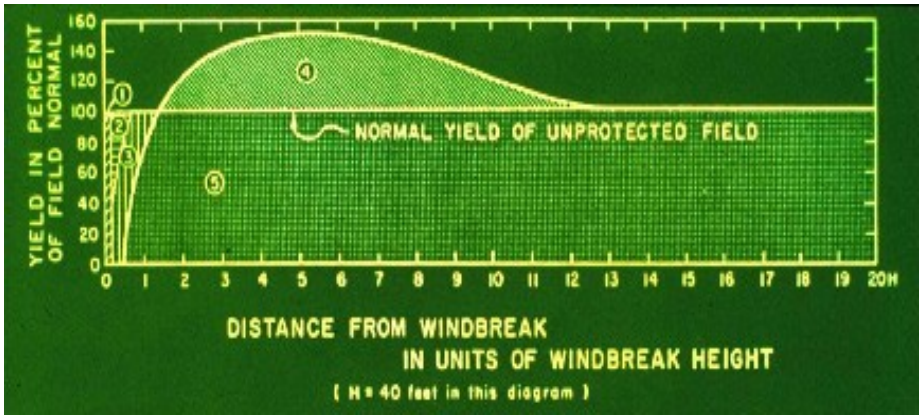


Fig. 3. Windbreak Benefits for Crops.

Crop Windbreaks: Weighted Average Crop Yield Increase			
Corn	12%	Soybeans	13%
Barley	25%	Winter Wheat	23%
Hay	20%	Spring Wheat	8%

Benefits for Crops

Windbreaks improve crop production and quality by modifying the microclimate and reducing wind erosion. They protect crops from insect pests by reduced crop visibility, dilution of pest hosts due to plant diversity, interference with pest movement, creation of environments less favorable to pests and more favorable to beneficial insects. They can be designed to manage snow drifting to maximize use of the moisture for crops. Windbreaks improve irrigation efficiency by reducing evaporation losses; and improve water quality through interception of sediment and interception, sequestration and decomposition of agricultural chemicals in the tree, shrub and herbaceous rhizosphere.

When field windbreaks are suggested to landowners, they often have a mental image of crop reduction and/or loss adjacent to the windbreak and from the space occupied by the windbreak. What is often not recognized is the potential for increased crop quality and quantity on the leeward (downwind) side of the windbreak. Many years of field research have shown there is a yield advantage for many crops when protected by a windbreak. This yield increase generally occurs from 1.5/2H to 10-12H on the leeward side of the windbreak (Fig. 3). The amount of yield increase will vary from year to year due to different weather conditions. There will also be some variation due to soils and the types of trees used in the windbreak (i.e., less competitive trees result in greater gains). The yield advantage is normally more than enough to offset the decrease in yield immediately adjacent to the windbreak and the land occupied by the windbreak. Some landowners will plant a deep rooted crop such as alfalfa adjacent to the windbreak in the area most impacted by competition and are able to gain good quality forage.

This field windbreak is designed to provide year-round protection by incorporating cedar and pine outer rows with an interior row of deciduous shrubs.

Benefits to Orchards and Vegetable Crops

In addition to the traditional commodity crops, windbreaks are also used to protect a variety

of horticultural crops including many fruit and vegetable crops. Some of the key benefits of protecting these types of crops include: improved crop quality from reduced bruising, better pollination from insects due to less wind, and early maturing of the crops resulting in possible marketing advantages. Windbreaks around orchards are also being examined for their use in preventing off-site drifting of pesticides. Many orchards and other farms are being engulfed by housing developments. Windbreaks can help buffer potential land-use conflicts.

Benefits to Livestock

Windbreaks provide valuable protection to livestock especially for young animals and in areas with cold northerly winds during winter and early spring. Reducing the wind impacts lowers animal stress and improves general health resulting better livestock production by increasing feed efficiency and weight gains, improving survival of newborns and increasing milk production. Windbreaks can also provide living screens to separate incompatible uses (i.e., livestock facilities from suburban residences).

Windbreak Design

Designing windbreaks requires the planner to be able to manipulate the different structural components of a windbreak in order to achieve the desired effect. Climatic and physical effects such as wind speed, apparent air temperature, snow deposition and evapotranspiration are modified as a result of the structural characteristics of the windbreak.

Ask Yourself: What needs to be protected?

- Crops/orchards
- Soil
- Livestock and/or Livestock Buildings

1) Determining the Windbreak Purpose

As noted previously, a windbreak can have a variety of purposes ranging from crop protection to snow management. The design of the windbreak is dependent upon the purpose(s) desired. To determine the purpose(s) requires understanding the desired objectives of the landowner and the physical site characteristics.

The first step in design is to interview the farmer/landowner to ascertain their objectives or purposes for the windbreak. A questioning strategy can be effective such as:

Crops

- *Have you had any wind erosion from your fields? If so,*
  - *o When did it occur?*
  - *o From which direction(s) does the wind cause the most problem(s)?*
  - *o Are you using other wind erosion control practices, e.g., reduced tillage?*
- *Have you had any crop damage or loss from the wind or blowing soil?*
  - *o When did it occur?*
  - *o From which direction(s) does the wind cause the most problem(s)?*
  - *o What crops are you growing that may be wind sensitive?*
- *Are you growing crops that need pollination?*

Livestock

- *When do your livestock need the most wind protection?*
- *What livestock pastures, lots or structures need wind protection?*
- *Do we need to be concerned with summer air movement in the livestock area?*
- *Which access roads need to be kept clear of snow?*
- *Is there a drainage issue associated with rain or snowmelt runoff?*

2) Site Evaluation

The next step is to evaluate the site conditions that may affect windbreak design and application. Use a conservation plan map or photo to identify fields in need of protection, existing windbreaks, soil problems, utilities, direction of prevailing erosive winds, property lines, roads and access lanes. (Fig. 4, next page.)

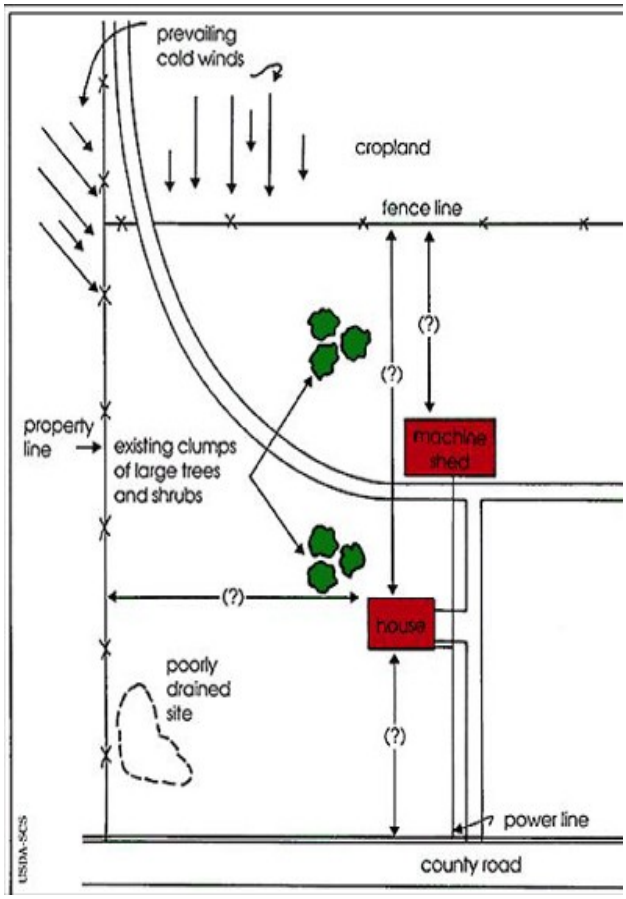


Fig. 4. Area sketch for site evaluation.

- Identify all areas needing protection based on the troublesome wind direction(s).
- Inventory the soils. Begin a starter list of species adapted to the soils.
- Observe the topography to determine any drainage concerns either into or away from the windbreak (especially snowmelt and feedlot runoff)
- Locate property lines, overhead and underground utilities (electric, telephone, gas, and/ or sewer), and existing trees or shrubs which may be within or adjacent to the proposed windbreak.
- Identify any access roads or lanes that could cause breaks in the windbreak.
- Locate the windbreak to avoid obstructing the winter sun, or oncoming traffic near driveways.
- Identify protection needs for the windbreak, such as fencing to keep out livestock.
- Observe any existing plant species which may be alternate hosts for pathogens, e.g., cedar-apple rust.
- Inventory existing wildlife habitat and wildlife species in the area so the windbreak may complement.

3) Design Considerations for Different Windbreaks

Windbreak Design Tips for Crop Fields

- For crop protection/production and/or uniform snow distribution, windbreak-to-windbreak intervals should be 15 to 20H. For crops highly susceptible to damage from wind or small amounts of wind-blown soil during some portion of the growing season, a spacing interval of 6-10H provides a high degree of protection.
- For erosion control purposes, the Natural Resources Conservation Service uses a rule-of thumb of "no erosion out to 10H leeward" -- leading to a windbreak-to-windbreak interval of 10H plus the distance protected by the agronomic system (i.e., standing crop, crop residues, cropping pattern, ridging) being used.
- Different design densities and heights result in different snow drift patterns. For example, if the landowner wants to spread snow evenly across a field to improve soil moisture in a crop field, the windbreak design density should range from 25 to 35 percent. This would be roughly equivalent to a single row of deciduous trees without leaves at a wide spacing (15 to 20 feet). If soil erosion is a potential problem during the time the windbreak is at this density level, additional conservation measures will be needed.

- ***Plan for 40-60 % density for crop and soil protection.***
- ***Plan for 25 - 35% density for snow distribution.***

Windbreak Design Tips for Livestock

- Greatest wind protection occurs from 2H to 5H leeward of the tallest tree row.
- For wind and snow protection, the most windward row needs to be 100 to 200 feet from the windward edge of the primary protection area.
- Allow room for snow deposition outside of feeding area. Care must also be taken to accommodate the drainage both from the clean water runoff from the windbreak (i.e. snowmelt) and drainage from the livestock feeding area. Effluent from the feeding area can harm and sometimes kill trees and shrubs.
- Critical temperatures for beef cattle are determined in part by the condition of the coat. Below the critical temperature, livestock must expend more energy to keep warm.

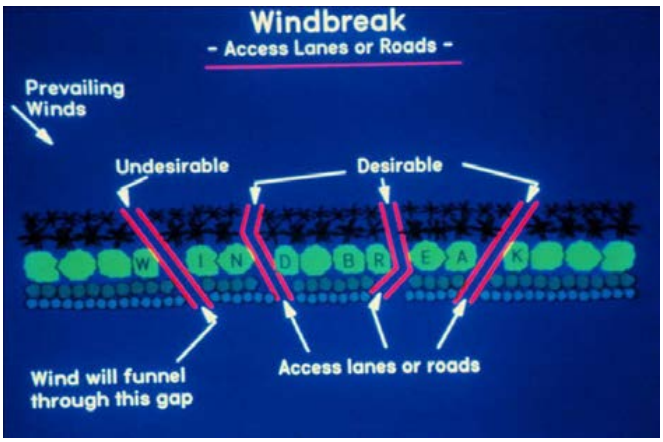
Livestock Critical Temperatures

Coat Description	Critical Temperature
Summer coat or wet	59^{o}F
Fall coat	45^{o}F
Winter coat	32^{o}F
Heavy winter coat	18^{o}F

Adapted from D.R. Ames, Kansas State University

General Design Considerations

- Avoid creating gaps with access roads cut through a windbreak. Wind flow increases through gaps decreasing windbreak effectiveness. Where needed, design the opening at an angle to prevailing winds. Lanes or roads through single-row barriers should be avoided; where necessary, locate them 100 to 500 feet from the ends of the windbreak.



- Locate new rows of trees 50 feet from existing trees.
- Stay away from subsurface drain fields and overhead utilities.
- Avoid locating windbreaks within 200 feet of road intersections to prevent poor driver visibility.

Selecting Tree and Shrub Species

All species of trees and shrubs do not grow at the same rate nor do they grow to the same mature height. Likewise, adapted species vary in their growth on different soils within a geographical area. The amount of available soil moisture during the growing season and soil aeration are two important factors affecting tree and shrub growth. These factors are largely determined by soil texture, soil depth and climate.

Conservation tree and shrub suitability groups have been developed as a guide for selecting species best suited to different kinds of soils, and climate, predicting height growth at 20

years, and measuring effectiveness. These guides should be available in the NRCS Field Office Technical Guide. Information about different plants can also be obtained from the USDA plants database at www.plants.usda.gov.

Windbreak Plant Materials
Select plants adapted to:
- Climate
- Soils

Select to meet objectives:
- Foliage density characteristics
- Height potential
- Wildlife needs

In addition to selecting plants adapted to the climate and soil, plants need to be selected that have the greatest potential for meeting landowner objectives. The primary objective is to select plants that will provide the desired level of wind protection in a reasonable length of time (within 10 years). This means selecting species that will give the appropriate level of density and optimum height for the site. For example, conifers need to be considered if optimum year-round wind protection is desired. If wildlife is desired, select appropriate plants for the desired animals or birds.

Productive Windbreaks

For most of the other agroforestry practices, e.g., Alley Cropping and Silvopasture, a market- able product is typically produced from the woody component. Windbreaks have historically been a conservation practice providing benefits to the adjacent area by reducing wind impacts. The trees and shrubs in a windbreak have rarely been managed to sell a product. In older windbreaks planted in the 1930's and 1940's, plants were chosen that could provide fruit for home consumption and trees were cut for use as fence posts and rough lumber on the farm. The concept of producing usable products from windbreaks and other conservation practices has recently been revived and promoted in Productive Conservation: Growing Specialty Forest Products in Agroforestry Plantings.

For example, nut and fruit producing plants could be incorporated into a windbreak design with the intent of harvesting the fruits/nuts as a product. The harvesting would not impact the other benefits of the windbreak. Some commonly harvested fruits include chokecherry, highbush cranberry, sand cherry, currants, Corneliacherry dogwood, jostaberry, Nanking cherry, chokeberry, buffaloberry, pawpaw, persimmon, and many others. All are harvested for home consumption, but many are also gathered for commercial use as fresh fruit, jams, jellies, syrups, juices, concentrates, confections and wines.

A second possible enterprise could be decorative woody florals. Any woody plant species that has a colorful or unusually shaped stem, bud, flower, fruit or even leaf can become a decorative floral product. Some plant examples include stems from red and yellow-stemmed dogwoods; and curly, pussy, flame and basket willows. Even though the stems of these plants will be harvested, most of them will re-sprout from the roots restoring their value as part of the windbreak.

With any of these concepts, careful advanced planning is needed. Some unique challenges include understanding available markets, timing of harvest, perishability of the product, available labor, wildlife pressure, year-to-year production, etc. Once these issues have been resolved, thought is needed to decide how to incorporate the plants into the windbreak design. If the plants that will be harvested are primarily shrubs, the design can be fairly easy since shrubs typically are included in the outer or inner rows which will make access easier.
Growing specialty forest products in windbreaks can provide supplemental income while at the same time improve the environment.
Another advantage is that the windbreak will receive more management care and could result in a longer lasting planting. Success will only occur if the grower is a skilled manager and an effective marketer.

Windbreak Site Preparation, Planting and Maintenance

Site Preparation

Site preparation is an important first step to ensure successful survival of the trees and shrubs in the windbreak. The goal is to maximize the amount of moisture at the site and to minimize the potential for weed competition. The type of site preparation used depends on the soil and existing vegetation at the site. With sandy soils, care must be given to avoid wind erosion problems. On sloping sites, precautions must be taken to prevent water erosion. Site preparation can be accomplished either mechanically (e.g., tillage equipment including chisel plow, disc, rototiller, or scalper), chemically (pre and/or postemergent herbicides) or a combination of both.

Site preparation

- Maximize moisture
- Minimize competition
- Match the site
- Be timely
- Care for plants
- Plant at correct depth

Planting

Tree planting methods include using either a tree planting machine or hand planting tools. For both methods, some key techniques need to be followed:

- Do not plant on hot, windy days.
- Prevent roots from drying out.
- Do not plant when the temperature is freezing or below.
- Plant seedlings in a vertical position with root collar 1" below soil surface.
- Prepare a trench or hole deep and wide enough to permit roots to spread out naturally; avoid "J rooting" - prune roots as needed to prevent J roots.
- Pack soil firmly around roots to eliminate air pockets.

In arid areas where trees are difficult to grow shrubs or tall native grasses may be used to provide crop protection, to control wind erosion, and to capture snow for crop production.

Maintenance

The goal is to maintain the health and vigor of individual trees and shrubs while maintaining the overall structure of the windbreak as an effective wind barrier. With proper care, a windbreak will serve a long life of protection.

Windbreak maintenance

- Weed/grass control for the first 3 to 5 years with optional cover crop between rows
- Use supplemental water to ensure early survival and development
- Replant to fill gaps
- Protect from animals and pests
- Use corrective thinning and pruning
- Do not fertilize (cost prohibitive)

- Weed/grass control: Weeds need to be minimized usually for the first three to five years in a band about three to four feet on each side of the rows of trees or shrubs. The area between the rows can be planted to an annual cover crop (e.g., grain/forage sorghum, oats, corn, millet, wheat, rye, or sunflowers) which can help control weeds, provide wildlife cover, and protect young tree seedlings from soil or wind abrasion.
- Supplemental irrigation: Irrigation (e.g., hand, drip, sprinkler, furrow or flood) is not a substitute for good site preparation and weed/grass control. Irrigation should be used when soil moisture conditions are extremely dry at planting time or during a prolonged drought after planting.
- Replanting: Replant all trees and shrubs that have failed in order to fill in the gaps in the windbreak. Replant annually for at least three years after the initial planting and continue until a full stand of trees is attained.

- Animal Protection: Establish appropriate fencing to prevent livestock and large mammal damage. Controlling small mammals can include repellents, traps, special fencing, and seedling protectors (e.g. photodegradable plastic tubing or mesh netting). Consult with local and state game/wildlife specialists for control measures for your area.
- Pest control: Periodic inspection of the crops and trees is recommended to detect and identify possible pests. These inspections and in some cases the use of pheromone traps will help determine when corrective action is warranted.
- Pruning: Hail, wind or snow storms often cause breakage of limbs and sometimes the main trunk(s) of the trees and shrubs. Remove broken limbs and tops.
- Fertilization: Generally, fertilization of windbreaks is not recommended. It is not practical, economical, or feasible, in most cases. The only situation where fertilization may be justified would be a small, high-valued windbreak planted on soils that have obvious soil nutrient deficiencies. Apply fertilizer according to soil test results.

Summary

Windbreaks protect crops, soil, and livestock while also improving air and water quality, broadening biodiversity, and beautifying the landscape. One of the keys to the successful windbreak is recognizing what the landowner wants to accomplish through its application on the landscape. The next step is to then under- stand the properties of a successful windbreak. And finally, choose species to plant in the wind- break that will enable it to work as expected. With a little planning upfront, a windbreak can provide a variety of benefits from improving crop production to maintaining livestock health.

Non-Agroforestry Uses of Windbreaks

1) Windbreaks for Homes

Benefits

Windbreaks reduce energy consumption by reducing air infiltration into buildings resulting in less heat loss and by reducing the amount of snow removal from roads and around buildings.

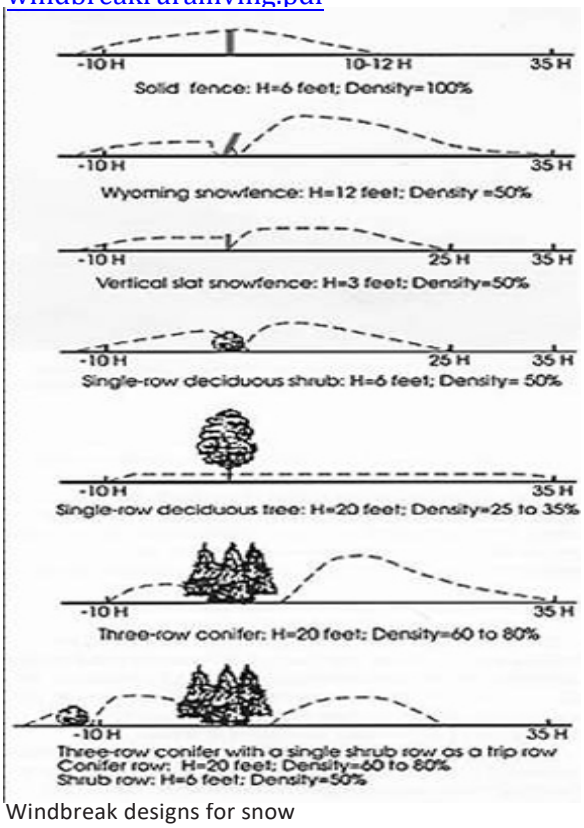
Design Tips

- For wind protection only, the tallest row needs to be 2-5H (H = planned height of the tallest row) from the primary area needing protection.
- However, for wind and snow protection, the most windward row needs to be 100 to 200 feet from the windward edge of the primary protection area. The distance between the area needing protection and the wind- ward row varies with the amount of space needed for snow storage.
- Once this critical distance is met, check to see if the area needing protection is still in the 2-5H zone, i.e. a house. Areas and objects more than 10H from the windbreak will receive reduced wind protection.
- To protect structures, the windbreak should have a density ranging from 60 to 80 percent during the period requiring maximum protection. To achieve the minimum level of this density range, plant at least three rows of trees and shrubs with at least one row being a conifer.
- Extend the windbreak a minimum of 100 feet past structures needing protection to accommodate wind turbulence at the end of the windbreak and end-drifts of snow.
- Locate access roads from 100 to 500 feet from the ends of the windbreak. If a lane must cut a windbreak, it should cut through the windbreak at an angle to prevailing winds to prevent funneling of wind and snow drifting.

Two designs for protecting a structure from snow

- **Traditional multi-row windbreak:** A basic farmstead windbreak consists of three to eight rows of both conifers and deciduous trees and shrubs. Conifers or shrubs should be located on the windward side with tall deciduous species in the center. A row of shrubs on the interior or leeward side completes the design.
- **Modified twin-row, high density windbreak:** In areas with frequent heavy snows consider adding a row or two of shrubs 50 feet to the windward side to trip snow before it reaches the main windbreak. An auxiliary planting of shrubs on the leeward side of the windbreak can also add good emergency cover for wildlife. This can be supplemented with a food plot between the main windbreak and the auxiliary planting.

For more information, visit "Windbreaks for Rural Living" at www.nfs.unl.edu/documents/windbreakruralliving.pdf



Windbreak designs for snow

Windbreak Design
To Protect Homes and Outbuildings

Windbreaks for protecting structures such as the farmstead, roads and other buildings:

Position the windbreak as close to perpendicular to the most troublesome wind direction. "One-leg" windbreaks are sufficient if winds come from one direction only, but a "two-leg" or network of windbreak(s) provides greater protection for variable wind directions.

Plan for 60-80 % density for maximum protection. Locate windward row 100 - 200 feet from area needing protection. In areas with variable winds, multiple-leg windbreaks provide greater protection to the field or farmstead than single-leg windbreaks.

Community Windbreaks

Planned community windbreaks can provide extra protection for the entire development and be an economic gain for the developer and homeowner from increased property values. Windbreaks in the rural-urban interface can also reduce potential conflicts, such as blowing dust, privacy, odors or noise between land uses. High quality windbreaks between agriculture and communities can prevent windblown soil and snow. Sediment in the yard, dust in homes and pesticide drift can be great aggravation to both rural and urban homeowners. *For more information see Working Trees for Communities,* https://www.fs.usda.gov/nac/documents/workingtrees/brochures/wtc.pdf

2) Living Snow Fences

Benefits

Blowing and drifting snow jeopardizes public safety and emergency services, interrupts businesses, increases road maintenance costs and causes wildlife mortality. Living snow fences are more cost-effective than structural barriers, can meet many additional objectives, and provide a wide array of benefits beyond snow control.

Design Tips

- To achieve maximum snow accumulation, the windbreak density should range from 60 to 80 percent.
- The most windward row should be a minimum of 100 feet from the area being protected to prevent inappropriate snow-drifts. This distance will vary (100 to 300 feet) depending on the location and severity of winters.
- A trip row of shrubs or dense conifer can be located 50 to 100 feet windward of the main windbreak to create a snow trap.
- For protecting roads, allow plenty of room for the leeward drift by locating the windward row of the windbreak 200 to 300 feet from the center of the road.

Below: Integrate windbreaks into an overall landscape design to achieve multiple objectives.

Refer to the windbreak design for snow figure for more guidance about snow behavior adjacent to different windbreak designs.

- Go to Working Trees: Living Snow Fences, https://www.fs.usda.gov/nac/documents/workingtrees/brochures/livingsnowfenceforweb.pdf, and Windbreaks for Snow Management, https://nfs.unl.edu/documents/windbre aksnowmgmt.pdf, for more information.

3) Windbreaks for Livestock Odor Reduction

Benefits

Windbreaks (or vegetative environmental buffers - VEBs) placed around livestock production facilities can help mitigate the movement of odors and dust generated by these operations. Urban expansion has placed many more people into closer contact with agricultural operations. Large scale livestock confinement production has led to increased concentrations of odor emissions travelling across highly modified landscapes relatively devoid of natural barriers. Windbreaks alone will not prevent these odor problems but can help reduce negative visual perceptions and the detection of smell by neighbors and surrounding communities.

Design Tips

- Windbreaks should consist of at least one to three rows of conifer and deciduous species.
- Two to three rows of trees can provide an ideal 60 percent windbreak density (or 40 percent porosity) for odor control.
- Shrubs are generally planted in the outside or inside rows, followed by conifers with deciduous hard- woods towards the middle or along the downwind side where they can grow more efficiently.

- Tree varieties and placement for the windbreak should be managed to maximize odor interception and dilution of air, and reduce odor leaving the source.
- Where site and facility conditions merit and allow, place plantings (not necessarily windbreaks) around the entire perimeter of the odor source.
- Even a site with a windbreak on one side that is strategically placed and designed can make a difference.
- For more information see Windbreaks: A "Fresh" Tool to Mitigate Odors from Livestock Production Facilities, https://lib.dr.iastate.edu/nrem_pubs/163/

4) Windbreaks for Wildlife Benefits

Benefits

With careful design, windbreaks provide nesting habitat for a wide variety of birds (up to 57 species) and other wildlife. Windbreaks can also produce needed food as well as protective cover when the wildlife forage in adjacent areas. Shelter from predation and escape cover as well as emergency cover from severe weather e.g., blizzards can be provided.

Design Tips

- Windbreaks can be given a more natural look and still provide excellent wildlife habitat and wind protection.

- **Connecting Habitats -** Where appropriate, select the windbreak site that connects to a larger habitat block such as a river corridor, woodlot, wetland, woody draw, or similar area.

- **Herbaceous Cover -** Consider planting or leaving herbaceous vegetation such as a mixture of grasses and legumes, standing grain, or crop residues as a border (20 to 50 feet wide) along the edges of the windbreak. If grasses or legumes are used, they should be separated from the new tree planting to avoid competition. This strip of cover can provide nesting, loafing, and foraging cover for a number of species.
- **Winter Cover -** Adding a shrub row 50 to 100 feet windward of the main windbreak as a snow trap results in greater wildlife protection on the leeward side of the main windbreak. Use species that will provide good thermal protection in the winter such as cedar and spruce.
- **Food -** Select species that may have high food value for a variety of wildlife. Planting food plots or fruit-bearing shrubs on the lee side of windbreaks provides food in an area protected from wind and possibly warmed by the sun, points that are particularly important in cold months.
- For more information see Windbreaks and Wildlife, https://extensionpubs.unl.edu/publication/9000016363670/windbreaks-and-wildlife/

Quail find excellent habitat in field windbreaks.

Success Stories

Paul Huenfeld, *Nebraska Producer Using Windbreaks with Organic Farming*

"Organic farming and trees were just a natural fit, like a hand and a glove, as far as I was concerned. We needed buffers around the farm. We also really value the importance of habitat for the insects and the predators, and we see that along the trees where we can plant grass and legumes is an excellent source of habitat for the different species of wildlife."

Claud Launius, *Retired cotton producer, Malden Plain, Mo.*

Claud Launius is a retired cotton farmer in the sandy soil area of "the Bootheel" of Missouri known as Malden Plain. "We were having a lot of trouble with blowing sand in the spring of the year; it was blowing and hurting our cotton pretty bad--killing some of it." Then, Natural Resources Conservation Service (NRCS) District Conservationist Phil Gurley told Launius about crosswind trap strips, and said he could get switchgrass seed through the Missouri Department of Conservation. Launius installed some on an 80-acre field in 1989. Although some cotton farmers have used wheat and rye to slow the wind, switchgrass grows to 6 or 8 feet and Launius says it keeps the wind up in the air. "In the spring, it's windy when the cotton plants are babies, and that's the worst time. If they get up to 6 or 8 inches tall they can defend themselves; but when they're short, with just two leaves, wind and sand can just cut them off. It's like a baby that gets sick--they don't grow like they ought to until they get well again. That's cotton, it's like any plant." When Launius retired he rented his land, and his tenant has kept up the wind strips.

Launius added four rows of switchgrass in strips with 24 rows of cotton. He figures he might have gone with 36 rows of cotton to 4 rows of switchgrass, "but I'd be afraid to tear any of it up." Besides, he's doing better with the 68 acres than he did with the original 80 acres. "Our yields have increased a half-bale per acre or more because the plants aren't getting hurt. They just sit there and grow; the weather doesn't bother them. We really like it." Launius is surprised that others aren't planting switchgrass wind traps, but thinks they just don't want to give up those 4 rows of cotton ground. He notes that there are other benefits beyond protecting the cotton plants and boosting production. "It's doing really well for quail and other animals, such as rabbits. By hiding in the switchgrass, the quail run the hunters crazy. The grass is really thick and it keeps get- ting thicker and thicker." To maintain it, every other 4-row strip is burned every other year; that makes the switchgrass "stool out" more, and then it has millions of seeds on it –"and that's what quail and wildlife like."

Economic Incentives

There are several agencies offering programs that can be used to establish and maintain windbreak practices on private land. The USDA Farm Service Agency (FSA) offers three programs that may be used for windbreaks and shelterbelts: the Conservation Reserve Program (CRP), the Continuous Conservation Reserve Program (CCRP), and the Conservation Reserve Enhancement Program (CREP). Each of these programs is designed to take environmentally sensitive and highly erodible land out of production by offering a soil rental payment, a cost-share for the establishment of various conservation practices and other financial incentives to landowners who offer to set aside their land.

Of these three programs, the CCRP program offers direct benefits to landowners establishing a windbreak/shelterbelt. CCRP is a voluntary program that focuses on funding conservation practices (CP) protecting environmentally sensitive land. Landowners with eligible land who wish to enroll that land in the CCRP may sign- up at any time during the year. NRCS Standard 380 identifies the guidelines for establishing a windbreak for the CCRP. For more information, contact your local USDA/FSA office.

The USDA/NRCS has four main programs that offer funds for tree planting and agroforestry. They are the Environmental Quality Incentives Program (EQIP), the Wildlife Habitat Incentive Program (WHIP), and the Conservation Stewardship Program (CSP). In conjunction with the funding programs noted, the USDA/NRCS also provides technical assistance to landowners who are interested in conservation planning and application.

The USDA National Institute of Food and Agriculture supports the Sustainable Agriculture Research and Education (SARE) program. Of the three funding types available through SARE, only one, the producer grant, is aimed at the landowner. Landowners who submit accepted proposals can receive up to $15,000 to establish and maintain the sustainable practice that they propose.

See chart (next page) for a listing of incentives offered by these federal agencies or consult the UMCA publication “Funding Incentives for Agroforestry in Missouri.”

Federal Agency and Programs Offered	Programs Available for Alley Cropping	Key to Programs
USDA/NRCS		• CS = Cost Share (ranges from 50% to 90%, based on a predetermined expected cost structure) • PP = Practice payment derived for each particular practice • LE = Land Easement (Rental payments based on an average rental rate per land use type; easements are typically 5, 10, 15, 30 years or permanent) • M = Annual maintenance payments (range from $5 - $10 per acre) • IP = Additional incentive payments (payments could include sign-up bonuses, additional cost-share, and/or increased land easement rates) • G = Grants
Environmental Quality Incentive Program (EQIP)	PP	
Wildlife Habitat Incentive Program (WHIP)	PP	
Conservation Stewardship Program (CSP)	CS, LE	
USDA/FSA		
Continuous Conservation Reserve Program (CCRP)	CS, LE, IP, M	
USDA SARE		
Producer Grants	G	

Additional Resources

Windbreak Resources – USDA National Agroforestry Center
https://www.fs.usda.gov/nac/practices/windbreaks.shtml This page has many windbreak references; we suggest starting with the 11 publications listed under the Windbreak Series heading starting with How Windbreaks Work. The Agroforestry Notes also provide some specialized information.

NRCS Windbreak Information
NRCS State Windbreak/Shelterbelt Establishment Practice Standards and Specifications:
https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/?cid=nrcs144p2_027140

Illinois
Illinois Windbreak Manual – Illinois Department of Conservation, Extension and NRCS:
http://web.extension.illinois.edu/forestry/iwm_complete.pdf
Iowa
Planning Farmstead Windbreaks - Iowa State Extension
https://store.extension.iastate.edu/product/Farmstead-Windbreaks-Planning

Farmstead Windbreaks: Establishment, Care and Maintenance - Iowa State Extension
https://store.extension.iastate.edu/product/Farmstead-Windbreaks-Establishment-Care-and-Maintenance

Minnesota
University of Minnesota, Morris "Selecting Trees and Shrubs in Windbreaks"

https://morrisonswcd.org//?s=windbreaks

Missouri

Using Windbreaks to Reduce Odors Associated with Livestock Production Facilities – USDA NRCS-MO – IS- MO380: www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs144p2_010805.pdf

Nebraska
Windbreak Design – University of Nebraska Extension NEBGuide G1304:
http://nfs.unl.edu/documents/windbreakdesign.pdf

Wisconsin
Windbreaks: Trees as Technology for Protecting Wisconsin's Topsoil – University of Wisconsin:
www.cias.wisc.edu/crops-and-livestock/windbreaks-trees-as-technology-for-protecting-wisconsins-topsoil/

Windbreaks That Work – Wisconsin Department of Natural Resources: dnr.wi.gov/topic/forestmanagement/ documents/pub/FR-070.pdf

Additional Resources, cont'd

In Print:

Brandle, J.R., L. Hodges, J. Tyndall, and R.A. Sudmeyer. 2009. IN: North American Agroforestry: An Integrated Science and Practice (H.E. Garrett, Editor). 2nd Edition. Agronomy Society of America, Madison, WI. Pp. 75-105

Brandle, J.R., L. Hodges, and B. Wight. 2000. IN: North American Agroforestry: An Integrated Science and Practice (H.E. Garrett, W.J. Rietveld and R.F. Fisher, ed's.). Agronomy Society of America, Madison, WI. pp. 79-118.

Brandle, J.R., D.L. Hintz and J.W. Sturrock. 1988. Windbreak Technology. IN: Agriculture, Ecosystems and Environment, 22/23. Elsevier Science Publishers. Amsterdam, The Netherlands. 598 pp

EXERCISE: REVIEW OF WINDBREAKS

1. What are the advantages of windbreaks for:

- **Cattle**
- **Soil**
- **Crops**

2. How far from the windbreak will crops benefit with increased yields?

3. Compare and contrast the uses for single-row and multiple-row windbreaks.

4. When considering whether to use single or multiple row windbreaks, what factors should be considered?

5. When deciding between deciduous and coniferous species, what factors will also be used when writing out the management plan?

6. Putting in a windbreak will cause a farmer to take acres out of production. How can you persuade a farmer that putting a windbreak in will be beneficial in the long run?

7. What financial assistance programs are being funded through state or federal programs to help landowners with the cost of putting windbreaks up on their property?

8. A number of features must be analyzed prior to the placement of a windbreak. List four of these features.

For further thought:
Like any other aspect of agroforestry, windbreaks can provide advantages and disadvantages to the landowner. How do you work with the landowner to see past the disadvantages and not focus on the negative?

EXERCISE KEY

1. What are the advantages of windbreaks for cattle, soil and crops?
Properly designed windbreaks have been shown to increase crop yield for a wide variety of crops. Decreases in wind speed protect downwind crops, decreasing evapotranspiration and increasing water use efficiency. Decreasing wind speed enhanced soil stability and is the primary basis for the installation of windbreaks dating back to the Dust Bowl of the 1930's. During the winter, cattle use energy to keep warm, increasing their feed requirement. Windbreaks moderate winter temperature extremes, reducing cold stress. Windbreaks also improve calving success rates.

2. How far from the windbreak will crops benefit with increased yields?
The rule of thumb is that crop yields are improved out to 10-15H.

3. Compare and contrast the uses for single-row and multiple-row windbreaks.
Single-row deciduous windbreaks are designed to improve snow distribution across a crop field to improve moisture for early season crop growth. They are also used surrounding orchards to still the air and improve pollination and/or speed up crop maturation. They may also be used as a visual screen along roads. Other windbreak applications depend on multiple-rows of deciduous and coniferous trees and shrubs, combined and configured for specific purposes (i.e., crop production, animal protection, snow fences).

4. When considering whether to use single or multiple row windbreaks, what factors should be considered?
The purpose of the windbreak dictates the design.

5. When deciding between deciduous and coniferous species, what factors will also be used when writing out the management plan?
Both conifers and deciduous trees bring different attributes to the function of the windbreak. Deciduous trees are more porous to wind movement, and are less effective in slowing wind speeds. Conversely, deciduous windbreaks reduce wind velocity further downwind. Conifers provide much more wind blockage, critical to protect cattle from wind and snow and roads and buildings from snow buildup.

6. Putting in a windbreak will cause a farmer to take acres out of production. How can you persuade a farmer that putting a windbreak in will be beneficial in the long run?
A realistic assessment of the farmers' goals and objectives, coupled with a similar assessment of the entire farm and cropping system, will lead to the diagnosis that may include establishment of windbreaks. Evidence of windblown soil erosion and associated crop damage, need for cattle protection or protection of buildings and roads, may all lead to this diagnosis. Once the diagnosis includes windbreaks, the next step is to explore cost share programs that may help to offset establishment costs. Visits to other landowners that have functioning windbreaks, will be very effective in addressing farmer concerns.

EXERCISE KEY, con't

7. What cost share programs are being funded through state or federal programs to help landowners with the cost of putting windbreaks up on their property?
EQIP and CCRP both provide cost share for windbreak installation. (see "Funding Incentives for Agroforestry in Missouri" for a thorough discussion of available cost share programs).

8. A number of features must be analyzed prior to the placement of a windbreak. List four of these features.
Height, density, orientation, length, width, uniformity, cross sectional shape.

Notes